I. B. S.
TECHNICAL DATA
BOOK

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INTERCOLLEGIATE BROADCASTING SYSTEM

TECHNICAL DATA BOOK

THIRD EDITION

Information Contributed

by

IBS Technical Department Staff

David W. Borst

Editor

A binder for Technical Information Sheets issued by the I.B.S. Technical Department

INTERCOLLEGIATE BROADCASTING SYSTEM

TECHNICAL DATA BOOK

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WIRED-RADIO BROADCASTING

GENERAL

A new type of program is now available to listeners in the dormitories and fraternities of a growing number of American colleges and universities. These programs are produced and engineered by the students of the institution, and are transmitted through a unique distribution system to various areas where the students are housed. The buildings within these areas receive the programs by direct radiation from the terminals of the distributing system in [illegible] at any standard radio broadcast, on a [illegible] broadcast band which does not interfere [illegible] services. When properly designed, the [illegible] distribution systems may be controlled [illegible] signals will be confined primarily to the [illegible]

[illegible] of this nature, to a specific [illegible] transmission system feeding radiating [illegible] small areas rather than by [illegible] signals radiated over a wide area [illegible], must be carried out in accordance [illegible] 15.1 [illegible] 15.4 of the Rules and Regulations of [illegible] Commission. These rules are given [illegible] 1 [illegible] If a transmission system is operated [illegible] rules, no station or operator's [illegible]

[illegible] confined method of broadcasting offers [illegible] broadcasting by other means. The [illegible] are:

[illegible] or station license needed, enabling [illegible] operate the station.
[illegible] broadcasts are only to student body the [illegible] better adapted to student management than [illegible] a standard broadcast station.
[illegible] expense of the station is small and [illegible] expansion program will permit growth [illegible] desired.
[illegible] given to students can be as complete [illegible] in the case of a standard broadcast [illegible] students with very little experience [illegible] to operate the station without [illegible] to the school.

[illegible]

[illegible] 15.1 [illegible] 15.4 have been interpre[illegible] [illegible] total electromagnetic field [illegible] of 157,000/frequency (Kc) ft. [illegible] and other transmitting and radiating [illegible] radio waves should not exceed 15 microvolts

per meter. FCC press release dated November 21, 19[illegible] further amplifies Rule 15.2 , paragraph (c) with the following footnote "For wired wireless systems the term [illegible] is interpreted to mean the nearest point of the conductors carrying the radio frequency currents".

In General Information Release 54246 dated October 24, 1941, the FCC further states:

"In the intercollegiate broadcasting systems communication is effected not by the transmission of radio waves through space but by the [illegible] radio frequency currents via wire lines. [illegible] of energy from the lines capable of caus[illegible] ference is prevented by proper shield[illegible] lines in metal conduit. You may [illegible] mation regarding the design of su[illegible] Mr. David W. Borst, Technical M[illegible] Intercollegiate Broadcasting Sy[illegible]

"Preliminary investigation[illegible] these intercollegiate systems [illegible] supervised. No interference ha[illegible] result of their use. The Commi[illegible] not promulgated any rules gover[illegible]

"This type of system, howev[illegible] lines or if improperly designed, [illegible] very serious interference. The [illegible] making a study with a view to the [illegible] in the case of extension of this [illegible] cation into other fields."

In a more recent release dated J[illegible] Federal Communications Commission reit[illegible] made above. Thus it can be seen that [illegible] tions on allowable radiation are adhere[illegible] for a campus station to secure a statio[illegible] for its operators. The FCC maintains [illegible] to facilitate making routine checks or [illegible] resulting from specific complaints or [illegible] which are found not in compliance with [illegible] close until remedial steps are taken [illegible] proved to the Radio Inspector involved. [illegible] Communications Commission conducted [illegible] stations of the Intercollegiate Broadc[illegible] that the allowable radiation limit was [illegible] degrees at these stations. These stat[illegible] to reduce their radiation to within [illegible] they found they could readily accomplish by [illegible] to their transmitters and employing [illegible] design of their RF transmission system[illegible] served to emphasize the need for [illegible] tion of the RF system [illegible]

FEDERAL COMMUNICATIONS COMMISSION RULES AND REGULATIONS

APPENDIX "A"

PART 15 - RULES GOVERNING RESTRICTED RADIATION DEVICES

§15.1 General.--Pending the acquiring of more complete information regarding the character and effects of the radiation involved, the following provisions shall govern the operation of the low power radio frequency electrical devices hereinafter described.

§15.2 Apparatus excepted from requirements of other rules.-- With respect to any apparatus which generates a radio frequency electromagnetic field functionally utilizing a small part of such field in the operation of associated apparatus not physically connected thereto and at a distance not greater than

$$\frac{157{,}000}{f.\ (kc.)}\ ft. \qquad \left[\frac{\lambda}{2\pi}\right]$$

the existing rules and regulations of the Commission shall not be applicable, provided:

(a) That such apparatus shall be operated with the minimum power possible to accomplish the desired purpose.

(b) That the best engineering principles shall be utilized in the generation of radio frequency currents so as to guard against interference to established radio services, particularly on the fundamental and harmonic frequencies.

(c) That in any event the total electromagnetic field produced at any point a distance of

$$\frac{157{,}000}{f.\ (kc.)}\ ft. \qquad \left[\frac{\lambda}{2\pi}\right]$$

from the apparatus shall not exceed 15 microvolts per meter.

(d) That the apparatus shall conform to such engineering standards as may from time to time be promulgated by the Commission.

§15.3 Exceptions; interference to radio reception.-- The provisions of sections 15.1 and 15.2 shall not be construed to apply to any apparatus which causes interference to radio reception.

§15.4 Inspection and test; certificates.--Upon request, the Commission will inspect and test any apparatus described in sections 15.1 and 15.2, and on the basis of such inspection and test, formulate and publish findings as to whether such apparatus does or does not comply with the above conditions, and issue a certificate specifying conditions of operation to the party making such request.

FAILITIES REQUIRED FOR WIRED-RADIO BROADCASTING

BROADCASTING STUDIOS

The ideal location for the campus station studios is in a centrally-located university building where a permanent installation may be made. At the very minimum, two rooms are required: one, a combined business office and reception room; the other a combined studio and control room. A control room separated from the studio by a double glass observation window is mandatory for all but the most elementary types of radio productions. Therefore, initial plans should include provision for the addition of a separate control room if it cannot be provided at the outset.

STUDIO AND CONTROL ROOM DESIGN

Sound treatment must be applied to the walls and ceiling of the studio. In the case of a temporary combined studio and control room, this sound treatment may consist of simple monk's cloth drapes on the walls and a sub-ceiling made of light cloth.

If possible, acoustical treatment using sound absorbing wall board or, preferably, polycylindrical diffusers should be installed on studio walls and ceilings.

Before installation of permanent sound treatment to a studio, the studio interior must be isolated from the adjacent room to prevent transmission of outside sound disturbances into the studio. This is done by building inner studio walls and a sub-ceiling, and laying a false floor on the original floor in the room. The interior wall sound treatment is then applied to the inner walls which have been constructed. This sound treatment is intended to give the correct acoustical property to the studio so that the pick-up of sound by the studio microphone will be natural in quality and not blurred by reverberation or unnatural-sounding due to absorption of certain sound frequencies by the studio walls.

When a permanent studio installation, such as described above, is contemplated, a separate control room should be included in the plans. This control room should be furnished with a double plate glass observation window. The two sheets of glass should be set parallel to each other, one sheet in the inner studio wall and the other sheet in the outer studio wall to preserve the sound isolation between the studio and the rest of the building. Both panes of the observation window should be sloped in toward the studio at the top as this will permit the control operator to look into the studio with a minimum of glare. If the two panels of glass are not set parallel, there is danger of multiple reflection of light which can be very

annoying.

The matter of selecting the studio dimensions is also of some importance in achieving the desired acoustical properties for broadcasting purposes. However, the studio dimensions are frequently determined by the building in which the studio is to be located and so the studio must be designed to fit into the existing space available.

Reference should be made to Section TI-5000 of this Data Book for more complete information on the selection of studio dimensions and satisfactory layout of studios and control room (Section TI-5100), the construction of sound isolating walls and ceiling (Section TI-5200) and the design of studio wall sound treatment (Section TI-5300).

PROGRAM INPUT EQUIPMENT

In order to meet the minimum requirements of the IBS Technical Code, the program input equipment of a station should include:

1) One 78 r.p.m. and one dual speed (78/33 1/3 r.p.m.) phonograph turntable, each with a suitable phonograph pickup for lateral recordings.

2) Two microphones.

3) A mixer, which will mix the two microphones independently, and the two phonographs independently; that is, it should have four input channels. It should be possible to switch to a remote line in place of one phonograph pickup.

4) Volume indicator meter connected to output of the mixer.

5) Headphone monitor if mixer is located in the studio, or loudspeaker monitor if mixer is in a separate control room.

Headphones are needed to monitor the program aurally as the volume indicator gives only a check on the program level and not on the content of the program such as the balance between the two microphones or a microphone and a phonograph pickup. Whenever possible, a loudspeaker instead of headphones should be used as the aural monitor, as the program will then reach the control operator in a more normal manner. If the control room and studio are combined, this loudspeaker should be provided, but it must be arranged to be cut off automatically whenever a microphone is placed in use. (If this is not done a feedback of energy will occur between the loudspeaker and the microphone which will interrupt the program.)

Even if the loudspeaker cannot be used when the microphones are in use it will be useful for monitoring recorded, remote and rebroadcast (such as FM) programs. If the speaker is connected to a good quality radio tuned to the campus transmitter, it will provide a check on the transmitter's performance.

Section TI-5000 of the Technical Data Book discusses the relation of audio systems to studio facilities. The design of amplifiers and mixers is covered by Section TI-2000. For information on microphones, phonograph pickup, turntable, loudspeakers, and similar devices, refer to Section TI-4000.

REMOTE PICKUP EQUIPMENT

A portable amplifier with one or more microphone input connections and having an audio output of approximately one-half watt, together with additional microphones, a headphone set, and a volume indicator, is required for remote pickup programs. Remote programs should be transmitted back to the studio as a low-level audio signal (plus 8 VU) over special lines erected or rented for that purpose. A system of jacks or switches for cutting the remote program in at the proper time through the program mixer (in place of one of the phonograph pickups, or through a separate channel designated for remote programs) is the most simple arrangement for placing a remote program on the air. Refer to Section TI-2400 for design information on remote pickup amplifiers.

When a local program loop rented from the telephone company or line erected on campus by the station staff are being used, switches can be provided to establish a talking circuit to the remote location. If a long distance telephone circuit must be used to bring in the remote program, it will not be possible to talk in the reverse direction over the line. As most remote programs will originate locally, it is very useful to have an arrangement which will permit the operator in the control room to talk to the remote operator while getting ready for the remote program. Also, it is possible to feed a cue signal from the control room to the remote point, this cue signal consisting of the last portion of the local program immediately prior to the start of the remote program. In this way, the remote announcer gets his cue to start his program from some pre-established phrase, such as the station break. When a long distance program circuit is being used, since it is not possible to send a signal in the reverse direction over the long distance line, it is necessary to make a toll telephone call to the remote location to confirm reception of the signal from the remote point and to indicate when the remote program should begin. Refer to Section TI-[illegible] for design of program, sending and receiving circuits.

ADDITIONAL STUDIOS

In the course of the station's growth, if not at the very beginning, at least one additional studio and control room

should be installed. It is important to have a large studio as well as a small one, as a great variety of programs can then be produced, and also the larger studio will make possible a studio audience. Another way to handle a studio audience is to originate the program as a remote broadcast from a local auditorium. Since many broadcasts will be recorded or transcribed, it is desirable to have a small announce studio or booth which can be used for these programs so that simultaneously a rehearsal may be carried on in any or all of the full sized studios which the station may have.

MASTER CONTROL FACILITIES

When the station has more than one studio and also when it begins to originate a number of programs from remote points, the need for a master control room having facilities for routing programs originating at these various points becomes apparent. The master control arrangement relieves the studio control man of all duties except those pertaining to the broadcast originating from that studio, thus permitting the control man to give his full attention to the program being produced. Also, better rehearsals can be conducted if the studio control room is not involved in the program going out on the air during the time of the rehearsal.

It is often convenient for master control to take care of originating recorded and transcribed programs, so a small announcer's studio or booth should be made part of the master control facilities. The master control equipment will then include a small mixer for this studio and for the phonograph pickup as well as the main program switching and routing circuits which permit master control to control the origination and transmission of the program.

If master control equipment is arranged in a logical manner, it will be possible for the campus station to originate more than one program simultaneously. The need for doing this will not often arise but there may be occasions when it will. For instance, the station staff might be asked to originate a program for some standard broadcasting station during the broadcasting hours of the campus station, making it necessary to originate two broadcasts at once. Facilities which will permit originating two broadcasts at once can also be used to record a live program at the same time a different program is being broadcast over the campus station. Such a recording might be used for a delayed broadcast of production over a local standard broadcasting station, or perhaps it is desired by the producer as an aid to rehearsing a radio program. In any event, master control equipment will permit the station staff to perform several operations simultaneously without having to set up a lot of special circuits for this purpose.

Many station designers prefer to install a master control room and announcer's studio before building a second large studio and control room. It is often possible to use an audi-

torium for programs requiring a studio audience, making it more important to provide good facilities for originating remote broadcasts than to provide a second studio and control room. A well-equipped master control room will permit a station to originate as well as receive programs over a wire network such as are often established between Member groups of the Intercollegiate Broadcasting System.

The relation of the master control facilities to the rest of the station facilities is discussed in Section TI-5000, and master control facility requirements are outlined in Section TI-5021.

SOUND EFFECTS

Sound effects equipment will be required if there is an active production group. Besides building up manual effects, such as a wind machine, etc., the station staff should invest in a library of recorded effects. A separate mobile amplifier and loudspeaker unit including two or three turntables and pickups should be built so that the recorded effects can be played in the studio and picked up by a studio microphone. This method of originating recorded sound effects gives much more satisfactory results than having the control operator mix the recorded effects with the program using the phonograph equipment intended for recorded shows.

TRANSMISSION SYSTEM

One of several means may be used to transmit radio programs from the campus studio to the receivers in the building in which reception is desired, and which means should be used depends upon local conditions. The basic desire at all times is to conduct the radio frequency energy the entire distance from transmitter (s) to each radio receiver. Any radiation which results will then usually be less than the maximum legally permitted. Attempts to radiate the program from the transmitter to the receivers have invariably resulted in illegal operation.

TRANSMITTER RATING

In most installations, one transmitter is required which is rated about five watts input to the final stage. Usually a crystal controlled master oscillator and class C r.f. amplifier circuit is provided. The r.f. amplifier is plate modulated by a suitable audio amplifier. The transmitter must be well shielded to prevent direct radiation. Further details on the design of transmitter is included in section TI-1000.

SELECTING TRANSMITTER FREQUENCY

In order to take the greatest advantage of the allowable radiation distance permitted by the FCC, a channel at the low frequency end of the broadcast band should be used. A survey of the channels between 540 and 700 kc. should be made and one chosen on which there is no loud signal, and also which is at least 20 kc. removed from all stations which can be heard well enough to provide good reception. If there is a local station in this range 30 or 40 kc. should be provided between this station and the campus transmitter as otherwise some radios may not be able to separate the two.

The channel selected should be as clear of other signals as possible; however, there is no channel in this range on which a station cannot be heard, especially at night, and so the campus transmitter should be crystal controlled and operated as close to the exact channel frequency as possible to avoid interference from other signals on the channel. Broadcast band channels are always some multiple of 10 kc. and operation on a frequency other than one of these should not be tried as interference from existing stations will invariably result. For a more detailed discussion of selecting the channel frequency and the right type of crystal, refer to Section TI-1100.

TRANSMISSION LINES

A very popular means of transmitting the energy of the transmitter to the student radios is by unshielded twisted pair transmission lines. In this case the transmitter feeds a network of these lines which run to all reception areas; each area being a building or group of buildings on different parts of the campus. There the lines are generally coupled into the electric wiring in the buildings, so that the r.f. poweris conducted directly to every radio operated by this electric power, or to within a few feet of every battery operated radio. Booster r.f. amplifiers are needed to cover a large area at the end of a long transmission line. If the transmitter power is increased, instead of using a booster amplifier, excessive radiation from the r.f. lines may result. It is best to limit the rating of the transmitter to about five watts input and install a booster amplifier for areas where the signal proves too weak.

The installation of twisted pair r.f. lines and the coupling devices required to couple them to the transmitter and to the A-c wiring in buildings is discussed in Section TI-3100.

OFF-CAMPUS RECEPTION AREAS

A location which cannot be reached by student erected lines, such as a building or group of buildings separated from the campus by one or more streets over which it is not permissable to erect a line, can be reached by renting a telephone

line. Rates for "broadcast program loops", usually based on the air-line distance between the ends of the loop, may be obtained by applying to the local telephone company business office. Audio signals are sent over this line and used to modulate a small transmitter at the remote end of the line which, by means of an r.f. transmission system, can be arranged to reach one or more buildings on the remote block.

If only one or a few small buildings must be reached in this way, a small one-half watt crystal controlled transmitter, such as the one shown on H1095, may be used to generate the r.f. signal. If large buildings are involved, a larger transmitter, which is the duplicate of the campus transmitter, may be required, rated about 5 watts. In some instances it may be necessary to make several installations of program loops and transmitters to reach all the important off-campus areas.

Section TI-3200 gives further information on audio lines and the coupling devices needed to feed the audio into and out of the line.

OTHER TRANSMISSION SYSTEMS

If a number of buildings have a common source of alternating current power at low voltage (208 or 220 volts), it may be possible to feed radio frequency power into the low voltage wiring at one point and cover all of these buildings. If the wiring carries considerable current, it may be found that a 15 or 20 watt transmitter is required. Extreme precautions against radiation must be taken with such an installation.

Similarly, where several buildings are fed with low voltage d-c power the power circuits may make a suitable wired transmission system. With d-c wiring, however, it is usually impossible to transmit the radio frequency energy more than a few hundred feet between buildings. A separate r.f. system with connections to the d-c wiring in each building provides the best answer.

In certain instances, such as when a university supplies its own a-c power, it may appear attractive to feed the radio frequency energy into the high voltage a-c system, with the expectation that it will then reach every building connected by the power lines. The high voltage coupling equipment needed in this case is expensive and difficult to install, since the voltage on the power system may be 2300 or 4160 volts, and in many cases good results are not always possible due to wide variations in the characteristics of high voltage wiring on different campuses. This method should not be used unless there is no other possible way to reach the area in question, and then only after careful study of the problem and consultation with the Technical Department of the Intercollegiate Broadcasting System.

ERECTION OF LINES

If heating tunnels exist on the campus, r.f. wiring should be installed in them to minimize damage to lines from weather and other causes. This wiring must be run with conductors capable of standing up under conditions of heat and moisture encountered in these tunnels. However, this disadvantage is offset by the fact that the lines will not be damaged by sleet, snow and similar causes.

When heating tunnels are not available, lines should be erected overhead by supporting them on buildings, and other convenient points. All connections to a-c or d-c power wiring should be made in a permanent manner through capacitors of adequate voltage rating and protective fuses should be provided. The fuses and capacitors should be mounted in a metal box in each case to prevent tampering or shock to personnel. Approval from the college authorities must be sought before installing any of this equipment. Section TI-3100 describes in detail preferred practices to use when installing r.f. transmission lines and coupling capacitors and fuses.

RADIATION CHECK

Once the transmission system has been installed, a careful check for radiation should be made. Tests for radiation should preferably be conducted with a field strength meter. A battery operated portable field strength meter with loop antenna is now available and a share in a meter of this type may be purchased by any station in the Intercollegiate Broadcasting System. If a portable field strength meter is not available, a very sensitive battery operated portable or automobile radio may be used. However, the readings obtained by means of such radios are only approximate and the final test of the r.f. system should be conducted, using a field strength meter in all cases.

A signal strength of 15 microvolts per meter is barely audible on even a sensitive portable or automobile receiver. It is roughly equivalent to the daytime signal produced 350 miles away from a 50 kw. station on 600 to 800 kc. If such a signal can be found in your locality it can be used to compare the radiation from your campus station.

You should conduct a radiation check on your station as soon as it is installed. The radiation from every transmitter, master r.f. amplifier, r.f. line and building you cover should be measured. If a-c wiring between buildings is used to carry r.f., it should be checked. Power wiring carrying r.f. as a result of indirect coupling must also be included in your measurements. The radiation must not exceed the amount specified in FCC Rule 2.102 (refer to page TI-111).

Excessive radiation can be reduced by installing shields around transmitters and r.f. amplifiers, reducing r.f. power, relocating lines, or re-arranging lines and putting in better coupling devices. The r.f. system should be re-checked at least once a year, and whenever changes are made.

TRANSMITTER DESIGN AND INSTALLATION

This section of the IBS Technical Data Book deals with the design, installation and operation of small transmitters for use in the AM broadcast band by campus stations. Simplicity of operation and at the same time reliability of performance, are important considerations in this service. Generating a large amount of power is generally not as important as generating a signal having low distortion, capable of a high modulation percentage and having a good signal-to-noise ratio. Frequency stability is also an important factor; in most cases crystal control offers the best means of obtaining this in a trouble-free circuit which is at the same time simple and low in cost.

Because the transmitter is the voice of the station, no matter how small its rating, its performance must be comparable to that of large commercial equipment. For this reason designs must be carefully worked out, and must embody good engineering practice. So called "phonograph oscillators" do not meet the necessary performance standards and should never be used in a campus station.

CONTENTS OF SECTION TI-1000

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TI 1003	Transmitter Standards Required by IBS
TI-1005	One Half Watt Transmitter
TI 1007	Six Watt Transmitter
TI-1009	Ten Watt Transmitter
TI-1011	Twenty Watt Transmitter
TI [illegible]	Reducing Transmitter Hum and Radiation of Harmonics
TI-1031	Transmitter Installation and Operating Instructions

Refer to "List of Drawings" at the beginning of the Technical Data Book, following "Table of Contents", for location of drawings referred to in this text.

The following paragraphs of the IBS Technical Code apply specifically to transmitters. They must be met when designing a transmitter for operation by an IBS member group.

EXCERPTS FROM TECHNICAL CODE

"Each Member (group) which operates or participates in the operation of a system disseminating programs through the use of one or more carrier-current systems or devices shall adhere to the following technical regulations and standards of good engineering practice:

a. No carrier frequency of less than 540 or more than 700 kilocycles per second shall be employed in such a system, unless higher frequencies are approved by the technical manager.

b. No carrier frequency shall be employed within 10 kilocycles per second of the carrier frequency employed by any standard station whose [illegible] microvolt per meter contour encloses any part of the service area of the station, or within 20 kilocycles per second of any station whose 500 microvolt per meter contour encloses any part of the service area of the system.

c. Each (programming) system shall meet the following standards of performance:

1. Transmitter modulation capability: 95% AM.

2. Distortion introduced after microphone or phonograph input: less than 7.5% R.M.S at 95% modulation measured at 1000 or 400 cycles per second.

3. Overall frequency response of system after microphone and phonograph inputs: flat within plus or minus 2db of the 400 or 1000 cycle response from 100 to 5000 cycles per second.

4. Carrier frequency stability: plus or minus 50 cycles per second under all operating conditions.

5. Noise and hum introduced after microphone 40 db or more below 95% modulation.

[illegible]

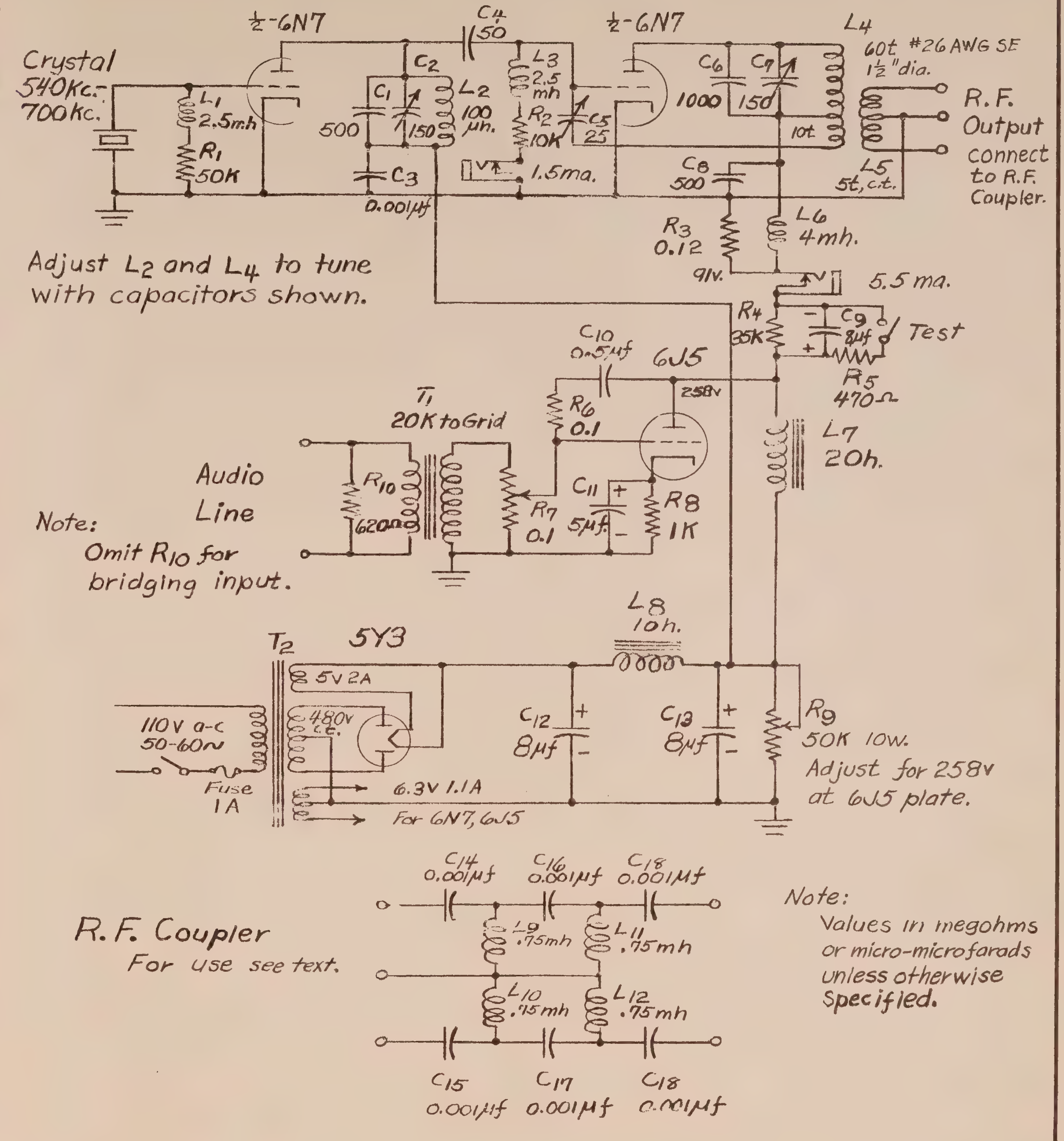
[illegible] it is necessary to cover a small area, the circuit [illegible] TI-095 [illegible] transmitter [illegible] very useful. This transmitter will successfully supply [illegible] signal for one large dormitory or it may be used to cover several small dwellings, such as a group of fraternity houses located close together. The transmitter is designed for telephone line input. This line may be a student [illegible] line or it may be [illegible] from the local telephone company. Refer to section TI-3200 for information on audio lines.

Discussion of the circuit

The transmitter shown is a crystal-controlled design as this is the only means to obtain the frequency stability required by the [illegible]. Self-excited oscillators can be built which will be quite stable, but they require the use of additional tubes and careful adjustment before their performance even approaches the stability that can be obtained by crystal control. [illegible] probably be left running continuously, and it is desirable that the circuit be of the utmost simplicity to minimize that possibility of failure. Furthermore, a small transmitter such as this is often placed in out-of-the-way locations where tuning adjustments are inconvenient, making a further reason for using crystal control in this case.

The grid leak resistor R_7 is shown with a value of 50,000 ohms. [illegible] precedence over the value shown in this drawing, if it is different.

The r.f. portion of this transmitter [illegible] make a good driver for a larger transmitter. [illegible] more fully in section TI-1151.



TITLE ONE HALF WATT TRANSMITTER

BEGUN BY D.W. Borst Feb. 18, 1946	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1095	GH-CM	
FINISHED BY D.W. Borst Mar. 12, 1946			PY	
REVISED:			DL	
			R	
			PRINTS TO	

SIX WATT TRANSMITTER

Application

The transmitter circuit shown on #1109 will have sufficient power for a small or medium-sized campus if the dormitories, fraternity houses or other dwellings can be reached over a system of twisted pair r.f. transmission lines as described in section TI-3100. The coverage of the transmitter may be increased by boosting the power at the end of long r.f. transmission lines with linear r.f. amplifiers, such as the one shown in section TI-1500.

Discussion of circuit

The transmitter is shown with an oscillator circuit which may be operated either crystal-controlled or self-excited. Crystal control operation is recommended for all but preliminary operation of the transmitter. If, at the start of operations, the most desirable channel frequency for the transmitter has not been determined, a grid leak tank coil may be wound and the transmitter operated as a self-excited unit. The oscillator has not been designed to give a high degree of stability when operated self-excited, however, and it will be found when operating in this way that the transmitter will drift.

If the transmitter is located close to the broadcasting studios and offices, it will be easier to keep the transmitter tuned to the correct frequency than it will be if it was located in some other building. For this reason, if a system is to employ a number of transmitters and it is desired to try various frequencies a few nights at a time until the best operating frequency has been chosen, one transmitter should be designed with the provision for self-excited operation, and it should be located in the same building with the studios. All other transmitters should be built as crystal-controlled units only, as it is very difficult to keep a number of self-excited transmitters properly in tune.

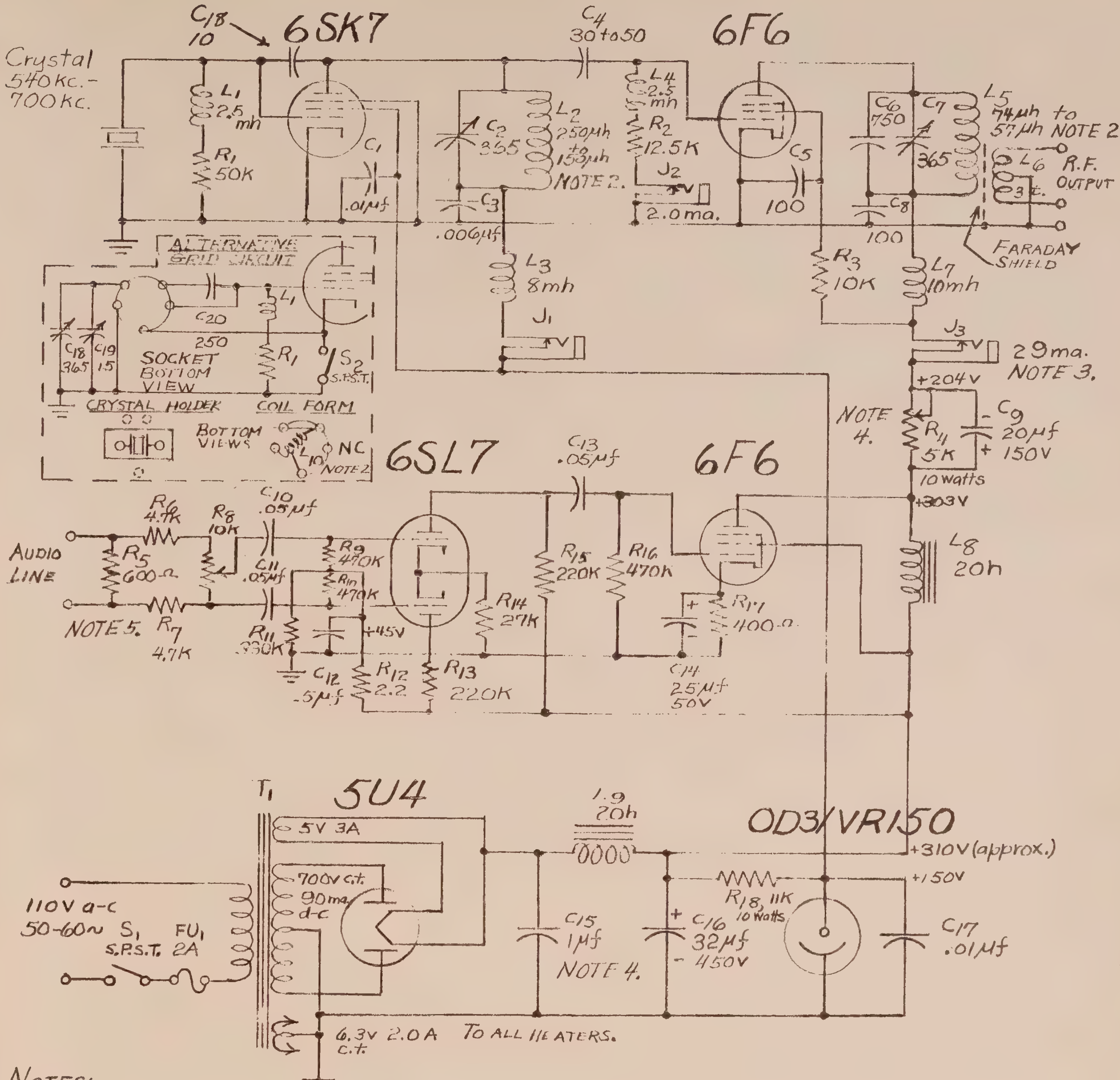
The audio input circuit in this transmitter is interesting because there is no input transformer. The circuit will operate from a balanced audio line and will give much the same performance as if it had an input transformer, but at reduced cost. If the transmitter is to be operated in multiple with other audio circuits, the 600-ohm resistor R_5 may be omitted so that the transmitter presents a bridging load to the line. If the line terminates at the transmitter then the 600-ohm resistor should be retained to properly terminate the line.

When tuning up the transmitter, R_4 should be adjusted so that 204 volts are available at J5 when the power amplifier is drawing a total of 29 milliamperes plate and screen current. It may be found that, in actual operation, loading the entire output of the transmitter into the r.f. line will result in excessive field strength and radiation. If this is true, then the best procedure is to load the excess power into a dummy load, such as a 25-watt, 110-volt lamp bulb, rather than operate the power amplifier stage at reduced loading. The modulator circuit has been designed to properly match the load presented by the power amplifier 6F6 stage when this stage is operating with 204 volts at 29 milliamperes.

Oscillator Circuit Details

The grid leak resistor R_1 is shown with a value of 50,000 ohms. This may not be correct for the crystal that is selected, and so the recommendation of the crystal manufacturer should be followed and take precedence over the value shown on M1108, if it is different.

Capacitor C_{18} is required only when a crystal is used; the 6SK7 has insufficient grid-plate capacity to produce oscillations unless it is added. Two insulated wires twisted together will provide sufficient capacity.



NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROMICROFARADS UNLESS OTHERWISE SHOWN.
2) INDUCTANCE VALUES FOR L_2 AND L_5 GIVEN AT 540 KC. AND 700 KC. INTERPOLATE FOR OTHER CHANNELS. L_{10} SAME AS L_2 WITH TAP 1/3 FROM GROUND END. WIND L_6 TO SUIT LOAD.
3) ADJUST LOAD TO DRAW 29 ma. AT RESONANCE.
4) ADJUST C_{15} TO OBTAIN "B" VOLTAGES SHOWN, IF NECESSARY. ADJUST R_4 PRECISELY.
5) OMIT R_5 TO BRIDGE AUDIO LINE.

TITLE SIX WATT TRANSMITTER

FILE REF.: T15.12

BEGUN BY D W Borst Jan 4, 1947		INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.			H1108		GH-CM / PY / DL / R
FINISHED BY D W Borst Jan 5, 1947							
REVISED: I Nov 2, 1947							PRINTS TO·

TEN WATT TRANSMITTER

Application

When r.f. power is distributed by means of twisted pair transmission lines, there will be fairly few instances when a transmitter is required having a greater output than can be obtained from the transmitter shown on Drawing H1122. In fact, while a ten watt transmitter may prove useful at a very large campus in general, less radiation will occur if the transmitter shown on Drawing H1108 is used and several r.f. amplifiers are installed to boost the power where it is necessary (such as at the ends of long transmission lines.)

Where it is necessary to employ shielded r.f. transmission lines, or where power is being fed into high-voltage a-c circuits, then the increased power obtained with this transmitter may be necessary.

Discussion of Circuit

It can be seen that this transmitter is somewhat more complicated than the one on page H1108, since a buffer stage has been included in the r.f. lineup, and the power supply feeds only the r.f. stages. Both of these features result in a more stable transmitter design and make it easier to obtain good audio quality. For this reason, this higher power transmitter may prove attractive, even though it is necessary to use only a fraction of the r.f. power available, and the rest must be absorbed in a dummy load.

The modulator stage is not shown, it being preferable in a transmitter of this size to make it a separate unit with self-contained power supply. A push-pull modulator stage should be used to get the audio power required for full modulation. Six watts at 2% RMS harmonic distortion are required. Suitable circuits are given in section TI-2300, amplifier H1102 is recommended.

Provision to use either self-excited or crystal-controlled oscillator circuits is included in this c transmitter, as was the case with the one on H1108. In this case, the self-excited oscillator will tend to be more stable because of the isolating effect of the intermediate power amplifier stage. Never-the-less, crystal control is the most reliable means of determining the frequency, and should be used in all cases except when testing various frequencies to decide which will be ultimately used.

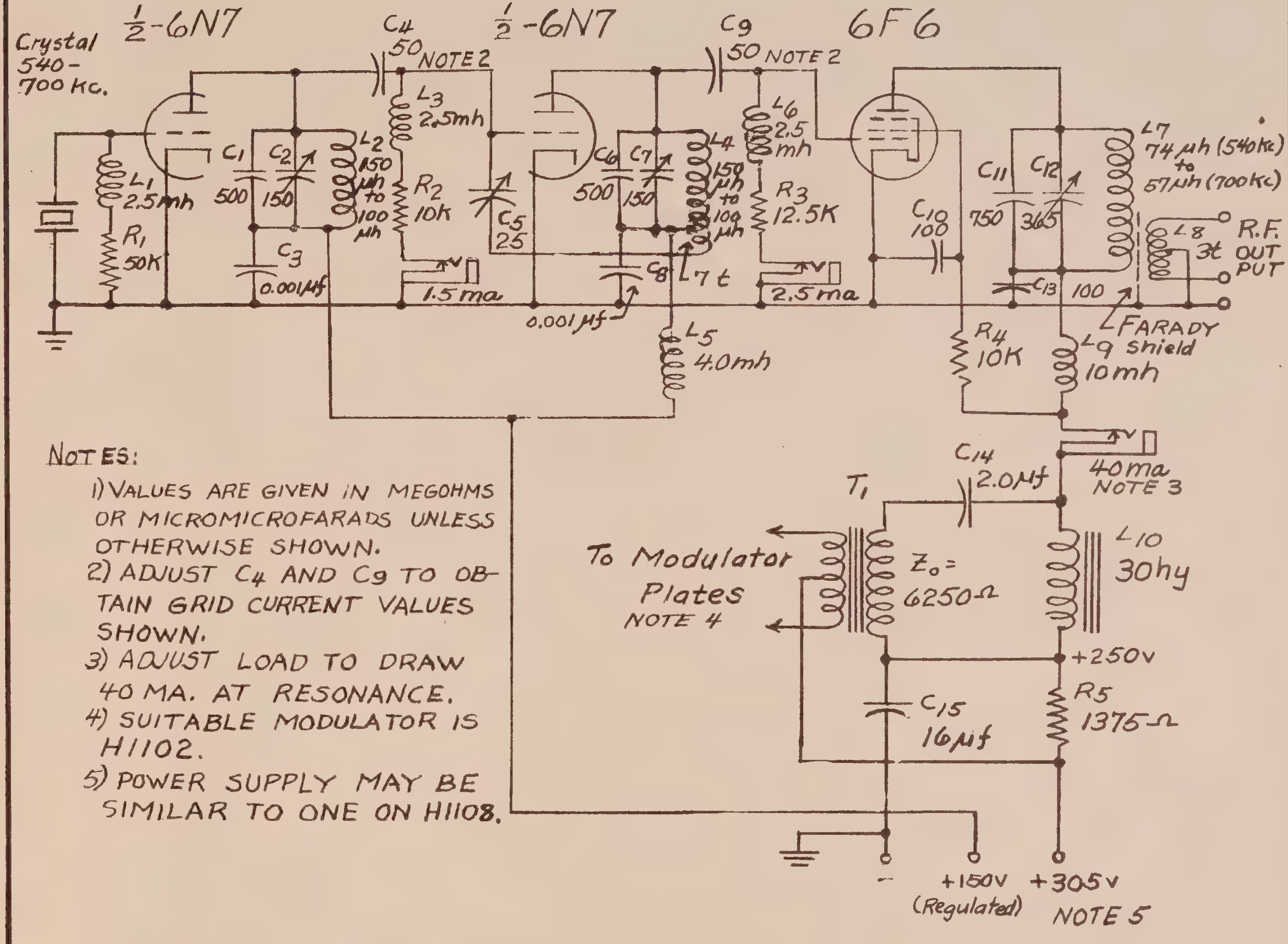
As with the case of the 6 watt transmitter on H1108 the transmitter should always be loaded to the degree indicated by the recommended plate current in the power amplifier stage, this loading to be accomplished by feeding power into a dummy load if the total power output of the transmitter cannot be utilized by the r.f. transmission system. If the transmitter is not loaded in this manner improper operation of the modulator will result, and the audio quality will be poor.

Increased Power Output

By raising the plate voltage on the 6F6 Power Amplifier stage to 275 v. increasing the rating of the power supply, and using a larger modulator, this transmitter may be operated at 14.2 watts input.

Larger Modulator

H1105 is then recommended for the modulator; at least nine audio watts are required. For further details, refer to section [illegible]



NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROMICROFARADS UNLESS OTHERWISE SHOWN.
2) ADJUST C_4 AND C_9 TO OBTAIN GRID CURRENT VALUES SHOWN.
3) ADJUST LOAD TO DRAW 40 MA. AT RESONANCE.
4) SUITABLE MODULATOR IS H1102.
5) POWER SUPPLY MAY BE SIMILAR TO ONE ON H1108.

TITLE TEN WATT TRANSMITTER

FILE REF. T15.12

BEGUN BY D W Borst June 9, 1947	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1122		CM
FINISHED BY D W Borst Nov 2, 1947				DL
REVISED:				R
				PRINTS TO

T152 7-7-45

30 WATT TRANSMITTER

Application

The 30 watt transmitter H-1081 will seldom be required to operate at full power output. The reason usually advanced for building a transmitter having this much power is to be sure that good audio fidelity is obtained. However, this requirement can just as easily be met by using transmitter H11[illegible]. 30 watt transmitter H1081 is included to permit comparing it with other designs having less power, and also to illustrate certain design features.

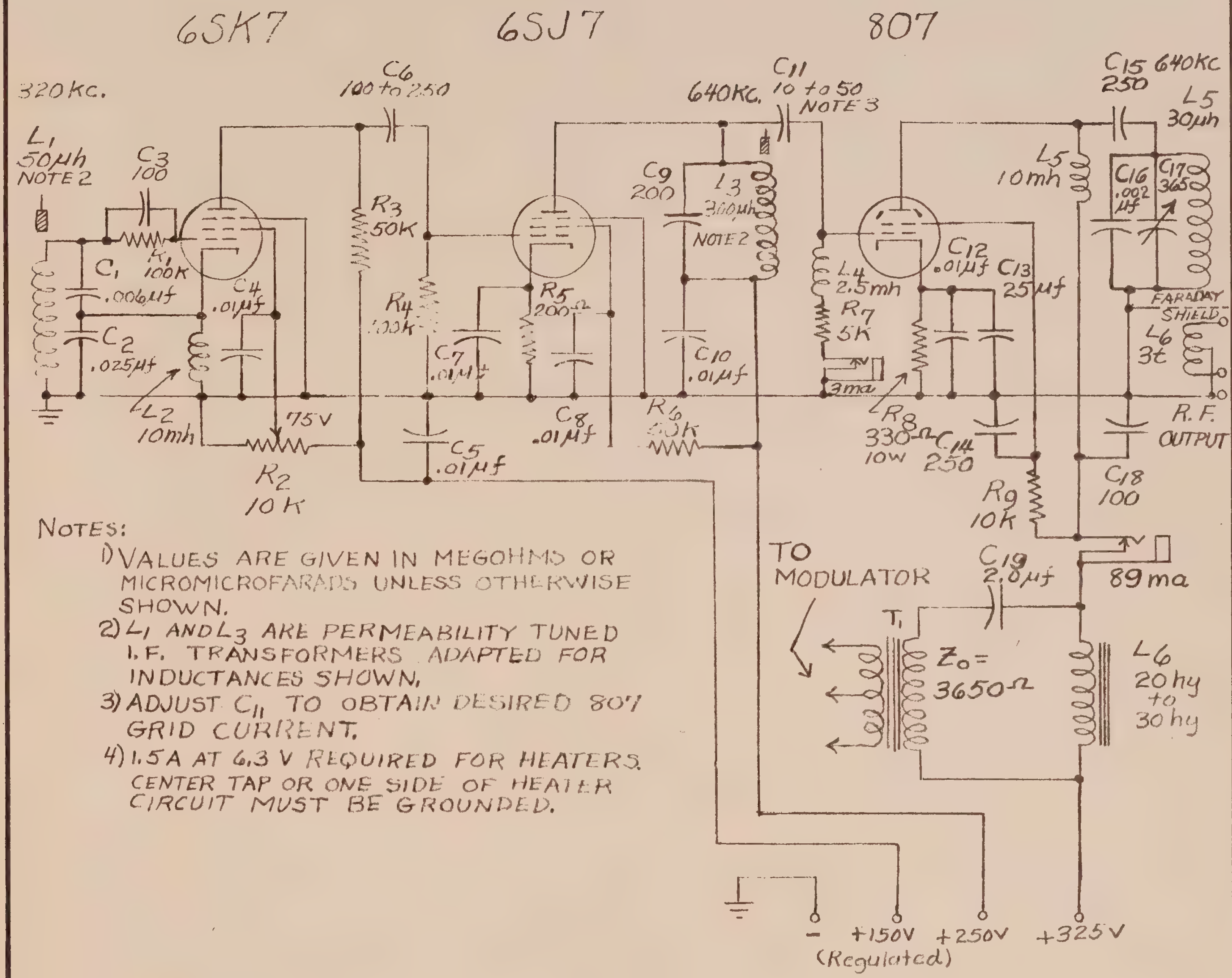
When feeding power into an a-c secondary network, or into high voltage a-c. lines, it may be desirable to have a transmitter with as much power as 30 watts. However, since this is not often the case, operation should first be tried using a transmitter of lower power rating, and only if no other means will successfully solve the problem of good coverage should a 30 watt transmitter be used. The smaller transmitter first used often can be continued in use for supplementary coverage. Construction of a 30 watt transmitter when it is not needed will result in an unnecessarily large investment.

A modulator to be suitable for use with this transmitter should develop at least 18 watts and no more than 2% RMS harmonic distortion. Such an amplifier can be built using four 6L6's in push-pull parallel or some similar tube combination. An amplifier of this rating is not included in the technical Data Book. Amplifier H1105 can be used for a modulator if transmitter H1081 is operated at reduced power input of about 20 watts. Transmitter H1081 can be operated at this reduced power by reducing the coupling between the power amplifier stage and the load. With 300 volts applied to the transmitter, the combined plate and screen current should read 67 milliamperes and the impedance to match the modulator becomes 4500 ohms.

Discussion of Circuits

The oscillator shown in this transmitter is of the self-excited type, having a pentode electron coupled oscillator and a pentode buffer stage. The transmitter has been drawn up to illustrate this particular oscillator-buffer circuit. However, it is recommended that the oscillator tube be operated crystal controlled as is shown on diagram H1108, or the oscillator and power amplidyne stages (the 6N7 stage) on diagram H1095 can be substituted for the oscillator and buffer stages shown on H1081.

In other respects, the operation of thismtransmitter is similar to that of H1122 since the 807 behaves very much like the 6F6



NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROMICROFARADS UNLESS OTHERWISE SHOWN.
2) L_1 AND L_3 ARE PERMEABILITY TUNED I.F. TRANSFORMERS ADAPTED FOR INDUCTANCES SHOWN.
3) ADJUST C_{11} TO OBTAIN DESIRED 807 GRID CURRENT.
4) 1.5A AT 6.3 V REQUIRED FOR HEATERS. CENTER TAP OR ONE SIDE OF HEATER CIRCUIT MUST BE GROUNDED.

TITLE THIRTY WATT TRANSMITTER

FILE REF.: T15.12

BEGUN BY DAVID LINTON July 23, 1945	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1081	CM DL R
FINISHED BY RETRACED DWBorst Nov 4, 1947			PRINTS TO
REVISED: 1 May 12, 1947 2 Nov 4, 1947			

SWARTHMORE TRANSMITTER

The schematic diagram of this transmitter is shown on H1123 and photographs of the unit follow this drawing. This Transmitter is included to illustrate good mechanical and electrical design features. Whereas the tube complement is sufficient for power input of 50 watts, in its present application at Swarthmore college it is running at about 25 watts input. A similar transmitter could be built with a single 807 in the final stage, which would give comparable performance.

Of particular interest is the method of mounting this transmitter on a 3-1/2" high rack panel. This mounting arrangement results in the tubes projecting horizontally from the rear of the chassis, where they can be easily inspected and changed. The crystal is also located in a similar position.

The transmitter chassis is built up of a number of sections of formed 0.050" steel sheets and in this way adequate shielding of all coils and isolation of the coils in the different stages is accomplished. The front panel was made of 0.125" cold rolled steel. The panel was zinc plated (not cadmium plated) to assure adherence of the black wrinkle finish which was applied to the front and edges of the panel. The steel chassis parts were also zinc plated to prevent corrosion by electrolysis between these parts and the back of the panel. If aluminum had been available, for the panel and chassis parts, the plating could have been dispensed with. The panel markings were engraved upon separate sheets of aluminum and fastened to their proper places.

An important electrical design feature is the d-c indicating instrument and selector switch which are mounted on the front panel of the transmitter. By means of selecting different shunts and multipliers, it is possible to use the same d-c instrument to measure all significant voltages and currents in the transmitter circuit. These measurements may be made at any time while the transmitter is on the air, which facilitates keeping an accurate and complete record of the transmitter performance.

Another interesting feature of this transmitter is the "off-the-air" monitor which is built into it. This consists of a 6H6 rectifier tube loosely coupled to the output circuit through a small capacitor. A 1N34 fixed crystal diode could be substituted for this tube and would eliminate the possibility of tube failure at this point.

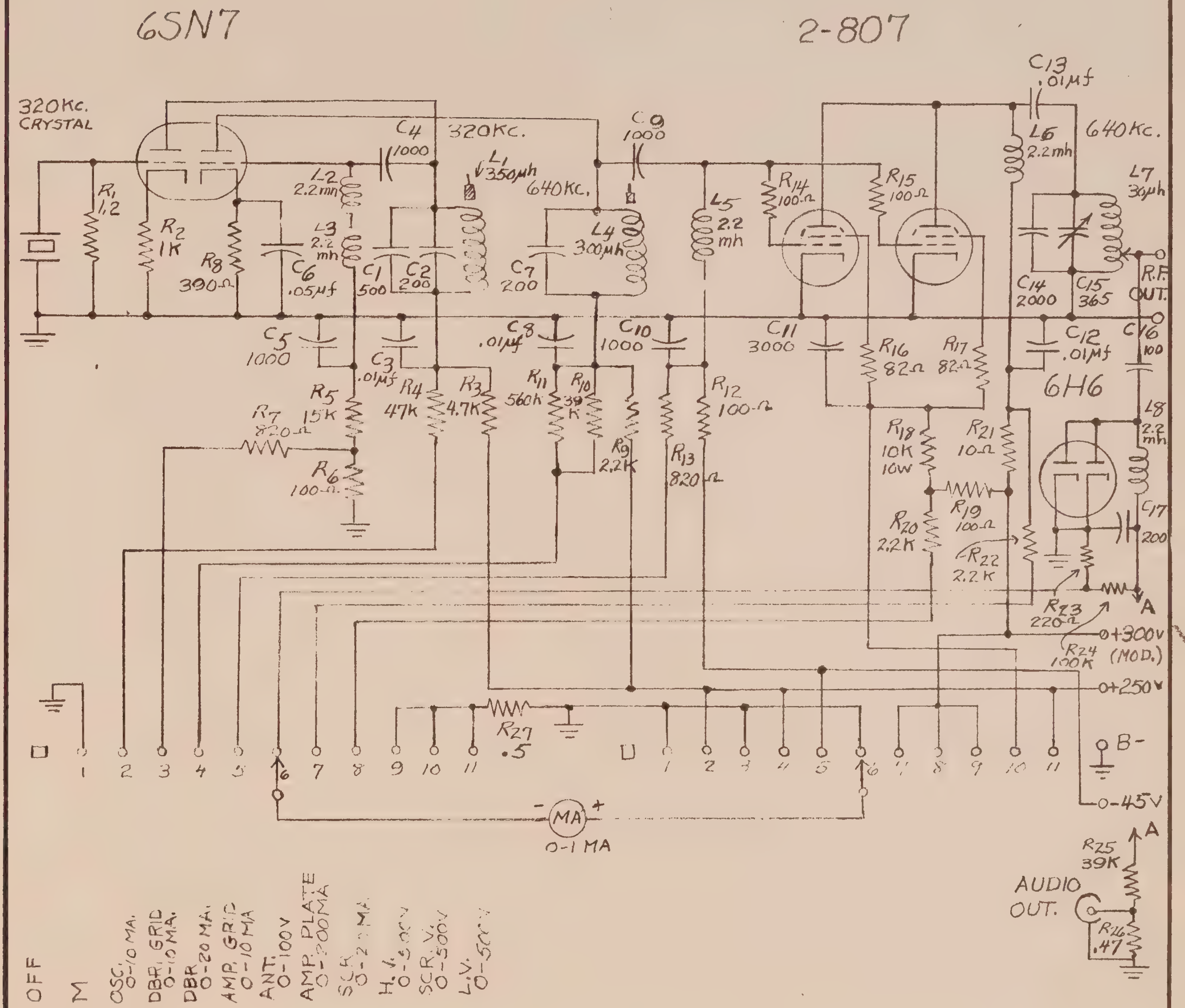
It will be noted that the output coil on this transmitter is arranged for single-ended feed to the transmission line coupling device. It would be permissible, of course, to utilize a balanced link coupling coil at this point. In this case the reading of r.f. output volts might have less significance and could be omitted.

Altogether, this transmitter is an excellent example of good design and it is hoped that the illustrations will inspire other stations to produce equally good units.

H1123

NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROMICROFARADS UNLESS OTHERWISE SHOWN.
2) 807'S LOAD TO 105 MA. PLATE CURRENT.
3) 2.4 A@6.3V REQUIRED FOR HEATERS. ONE SIDE HEATER CIRCUIT IS GROUNDED. TRANSFORMER IS MOUNTED ON TRANSMITTER CHASSIS.
4) L_1 AND L_4 ARE PERMEABILITY TUNED.



TITLE SWARTHMORE NETWORK TRANSMITTER

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FILE REF. T15.12

BEGUN BY D.W. Bont June 9, 1947 FINISHED BY D.W. Bont Nov 4, 1947	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1123
REVISED:		

T152 7-7-45

REDUCING TRANSMITTER HUM AND RADIATION OF HARMONICS

Carrier hum and radiation on harmonics of the fundamental frequency are two common troubles encountered in small transmitters used for campus broadcasting.

Carrier Hum

Three sources of hum may be contributing to this disturbance. First, is the obvious difficulty of too little filter in the d-c supply. This may be in one of the earlier audio stages, so for a test the modulator tubes should be moved, starting with the lowest level stage, meanwhile noting any decrease in hum.

Improperly grounded a-c heater circuits will cause hum. These circuits should be grounded. Either the center tap of the heater winding or, if that is not available, one side of the heater circuit should be grounded.

The third source of hum is backfeed of supply-frequency power into the transmitter plate circuit through the coupling device, if the transmitter is coupled into the a-c supply. In small transmitters, if appreciable power at the supply frequency is fed back, it may plate modulate the able hum. A capacity coupling scheme is especially likely to produce this difficulty. A good preventative is to couple the output of the transmitter into a second tuned circuit (an auxiliary tank circuit), coupling being done by a link having two or three turns. The a-c system should in turn be coupled to the auxiliary tank. If the midpoint of the link is grounded there will be little possibility of supply frequency energy getting back to the r.f. power amplifier plate circuit and causing hum.

Testing Precautions

Often it will be found that a transmitter will seem to have a lot of hum during initial tests and yet perform all right when installed. This may be the result of faulty test equipment or of the method used for performing the test. When listening on a receiver very close to the transmitter it may be that the oscillator (if it is a separate stage) radiates almost as much power as the modulated r.f. amplifier stage. This is especially true if the oscillator stage is not completely shielded. Thus, the percentage of modulation may appear low and hum may appear to be excessive. If the receiver being used for the test can be removed from the oscillator's field, or if the oscillator can be shielded, the hum will disappear.

Similarly it may be found that the receiver being used to test the transmitter is introducing the hum due to being in too strong an r.f. field (too near to the transmitter). Tune the receiver to a local station and notice if a hum is heard on this carrier. If a hum is present, chances are the receiver is at fault. Receivers with poor filter capacitors, and inadequate r.f. filtering in the second detector stage often introduce a hum on carriers which on better receivers are free of hum.

Harmonics

Transmitter harmonics are also quite strong near the transmitter, and may not appear to any extent on the r.f. transmission system. Harmonics can be reduced by proper design of the modulated Class C stage plate tank circuit, and by proper oscillator design. Sometimes, in order to achieve greater stability, an oscillator grid circuit is tuned to one half the frequency of the transmitter carrier. This procedure has the disadvantage that the third harmonic of the oscillator will be at 1½ times the frequency of the final carrier frequency. This is 1½ harmonic may ride through subsequent tuned stages and appear as a powerful harmonic. The best way to prevent this is to operate the oscillator on the fundamental frequency for the transmitter.

A properly designed tank circuit for the modulated Class C amplifier will reduce harmonics. Such a tank circuit should have a fairly large tuning capacity. Usually fixed and variable capacity totalling about 0.001 microfarads is required. This large capacity will be effective in bypassing harmonics to ground.

Stray capacity coupling between the tank and the r.f. transmission system, in cases where inductive coupling is employed will increase the magnitude of harmonics on the transmission system. A Faraday shield between the tank coil and the coupling coil will greatly reduce capacity coupling between them, leaving only the desired inductive coupling. Such a shield may be constructed of a number of parallel conductors jointed at one end by insulated from each other at the other end. The junction point of the conductors is grounded. For further details refer to the Radio Amateur's Handbook published by the American Radio Relay League.

Reference:

"Keeping Your Harmonics at Home" by George Grammer, QST, November 1946, page 13.

10/4/47

TRANSMITTER INSTALLATION AND OPERATING INSTRUCTIONS

I. INSTALLATION

The transmitter and the coupling device used to couple the transmitter to the transmission system should be thoroughly shielded to prevent radiation. A grounded metal case, with openings for adequate ventilation, or a grounded copper wire screen surrounding the transmitter and coupling device will do.

Place the transmitter in the location selected for its permanent installation. This should be a dry place, and if it is in the basement of some building, some reduction in direct radiation from the transmitter will result. If possible, do not mount the transmitter on the floor, or in some location where it will be subjected to shocks and jars which might cause the tuning capacitors to shift.

A source of power at proper voltage and frequency must be provided. The transmitter (and modulator, if a separate unit) should be equipped with a line switch and fuse, and in addition a master switch and line fuses may be provided if desired.

A line for carrying the audio signals from the studio audio equipment should be run to the modulator and connected to its input terminals. If the modulator has a bridging input, the line should be terminated in 600 ohms. If several audio devices are connected to this line, it should be terminated only at its end point.

If the transmitter is at any considerable distance from the studio, it should be kept as far away as possible from the line attached to its output terminals to prevent radio frequencies from appearing on the audio line and radiating from it. Twisted pair wire should be used for the audio line as this will minimize r.f. and noise pickup. If the audio line is a telephone circuit, it may be long enough to require equalisation. Measurements should be made to determine this and the line equalised if necessary.

The output of the transmitter should be run with twisted pair wire to the coupling means which is used to couple the r.f. into the transmission system. The link circuit between the transmitter and coupling device should be as short as possible to reduce radiation from the link, and to reduce transmission losses.

10/4/47

The modulator, if a separate unit, should be connected to the transmitter by means of a suitable cable. Both the transmitter and the modulator chassis, and also the transmitter shielding should be securely connected to a good ground.

II. OPERATION

Two means of frequency control may be used. Self-excited operation permits the frequency to be adjusted over a range while crystal controlled operation permits operation only on the frequency of the crystal or one of its harmonics. Often, self-excited operation is used at first, so that the most desirable of several frequencies can be selected after a trial of each. Then a crystal ground for the frequency selected should be obtained and crystal control used.

Self-Excited Operation

The power supply for the transmitter should be turned on, and the current in the oscillator plate circuit should be read. Usually a 0-15 milliampere meter will have an adequate range. The oscillator should be tuned to a frequency in the middle of the transmitter's frequency range by adjusting the tuning capacitor in the grid circuit. Then the turning capacitor in the plate circuit should be adjusted for minimum plate current.

If there is a buffer stage (intermediate power amplifier stage), it should be tuned for minimum plate current in a similar manner. The grid current in the buffer stage should be checked to be sure that the excitation provided by the oscillator is adequate.

If the final r.f. stage employs a triode tube, it must be neutralized. Remove plate power from the final stage and insert a low range milliammeter in the final stage grid jack, and check for correct grid current. Also, disconnect the lead from the output terminal of the transmitter. Now the final stage tuning capacitor should be tuned slowly across its entire tuning range; the meter, which is still in the grid circuit of the final stage, being watched for a slight deflection. If no deflection is observed, the final stage is properly neutralized. If a deflection is observed, rotate the neutralizing capacitor slowly until the minimum deflection is obtained. Perhaps it will not be possible completely to eliminate the dip of final grid current as a final plate circuit is tuned, but this dip should be made as small as possible.

When the final stage has been neutralized, the plate power

may be applied to this stage. The d.c. milliammeter should now be connected to the plate circuit of the final stage. A 0-50 milliampere scale will usually do. The final stage tank capacitor should now be tuned for minimum final plate current. The transmitter is now ready to be tuned to the desired operating frequency.

Tuning to Operating Frequency

If the operation of the transmitter has so far been satisfactory, it may now be tuned to the desired broadcast band frequency. One way to do this requires a communication type received equipped with a beat frequency oscillator. The receiver should be placed five or ten feet from the transmitter and tuned to the broadcast channel on which operation is contemplated.

With its beat frequency oscillator on, the receiver should be tuned to zero beat with the strongest signal which is heard. The receiver r.f. gain should then be reduced to minimum sensitivity. Then the transmitter should be turned on, and its oscillator tuned for zero beat with the communication receiver. If the transmitter has a buffer stage, the final plate power may be disconnected to reduce the r.f. field from the transmitter. The transmitter should now be completely tuned as previously described to this new frequency, except that it will not be necessarytto neutralize the final stage again, if this was required originally.

The lead to the coupling device should now be connected to the output terminals of the transmitter and the coupling device adjusted until the specified plate current is drawn by the final stage. Retune the tank capacitor after coupling to the load so that minimum current is obtained in the final voltage for the correct value as determined by the design of the transmitter.

If the output of the transmitter proves more then is needed to cover the area reached by the transmission system, the excess energy may be absorbed in a 25 or 40 watt, 110 volt lamp. Lamps of lower wattage rating will be difficult to couple to because their resistance is too high.

If there is a modulator transformer, its impedance must be adjusted by means of the tap provided on the transformer so that it will match the modulator impedance to the final stage impedance resulting from the power output conditions selected. The impedance of the final stage is found by dividing plate voltage by plate current. For example, with a 300 volt plate voltage and 40 milliampere plate current, the impedance of the

R.F. stage would be 7500 ohms. A modulation transformer should be adjusted to match this impedance to the primary plate to plate load resistance required by the modulator tube. By referring to the instruction sheet which is supplied with the modulation transformer, the impedance which most nearly matches the desired condition of operation may be chosen, and the transformer connected in the manner shown.

It may be necessary after these adjustments to recheck the frequency of the oscillator. This check may best be made at some distance from the transmitter to reduce the signal picked up by the receiver. It will be found desirable for the transmitter to have a vernier dial and small variable capacitor, as this will make it easy to adjust the transmitter frequency to be exactly the same as the frequency of the other stations or station on the broadcase channel used. By accurately setting the frequency of the transmitter in this manner, the beat note between the various signals on the channel will be a sub-audible frequency which will cause a minimum of interference.

Crystal Controlled Operation

For operation with crystal control a broadcast crystal of the proper frequency should be obtained in a holder which will mount in a five prong tube socket. The Bliley MC-85 holder is suitable but this holder does not have a variable air gap. If a holder is obtained (such as the Bliley BC-10 with variable air gap) which does not mount in a five prong tube socket, a mounting for it should be made.

The crystal should be installed in the transmitter. If the grid circuit shown on WL103 is used, the oscillator coil should be removed, and the crystal inserted in its place. The single pole switch is then turned to the closed position.

With power applied, the crystal oscillator plate capacitor should be rotated, and the plate current of the oscillator stage read on a suitable milliammeter. If the crystal oscillates, the plate current will suddenly dip to a few milliamperes. On one side of the minimum plate current point the crystal will suddenly stop oscillating as evidenced by a sudden rise in plate current as the tuning capacitor in the oscillator plate circuit is slowly turned. On the other side of minimum plate current, the plate current will increase slowly. The oscillator plate circuit capacitor should be adjusted a few degrees on the high frequency side of the point of minimum current as this results in the most stable operation of the crystal oscillator.

The grid current of the next stage should be checked to see if it is adequate. It can be increased by turning the oscillator plate circuit capacitor toward the point of minimum oscillator plate current, but this may result in crystal overheating and unstable operation of the oscillator.

The final stage should now be neutralized, if necessary, as described in the previous section under self-excited operation. The final plate circuit tuning capacitor should then be tuned for resonance as before and the output coupling adjusted in the same fashion.

If the frequency of the transmitter is now checked with a communications receiver, it will be found that with an accurately ground crystal the beat with the other station or stations on the broadcast band channel in use is a sub-audible frequency. If an audible beat note is heard, it may be possible to correct for this by varying the air gap in the crystal holder. Some holders are provided with a set-screw for this adjustment, which is usually reached by removing the nameplate on the holder. If this is not possible, the air gap may be changed by inserting a few pieces of thin tissue paper betweennthe crystal and the holder plates. However, this operation may reduce the activity of the crystal so that it will not oscillate.

Failure of the crystal to oscillate may be remedied by providing a slight capacitative coupling between the grid and the plate of the oscillator tube. A short insulated wire connected to each of these tube elements and twisted together a few times may provide the desired feed-back. Be careful not to increase the crystal current too much. The crystal current may be read on an r.f. milliammeter inserted in series with the crystal. Too much crystal current may result in crystal overheating and possible fracture.

Modulator

The adjustment of the modulator is fairly simple. With an audio signal on the line, the audio gain control should be increased until a slight deflection at the time of modulation peaks is noted on a meter inserted in the plate circuit of the transmitter final stage. The audio gain should then be reduced slightly from this setting. If an audio oscillator is available, the transmitter should be adjusted for 100% modulation at a level 10 db. above the 100% calibration point as read on a standard VU meter connected across the line to the transmitter. This provides a 10 db. margin for sudden peaks.

100 percent transmitter modulation can best be determined by using a cathode ray oscillograph with its horizontal deflection plate connected to the output of the modulator and its vertical deflection plate coupled directly to the r.f. output of the transmitter. A triangular pattern indicates 100% modulation. This method of measuring modulation percentage is fully described in the ARRL- "The Radio Amateur's Handbook".

Operating Procedure.

If continuous operation of the transmitter is contemplated, adequate ventilation for it should be provided. The transmitter should be inspected at weekly intervals, the plate current recorded in a log at this time, and stages retuned if necessary.

If the transmitter is located in the broadcasting studio or control room, and if it is self-excited, its frequency should be checkedonnce every day. If the transmitter is located at some distance from the studio and is self-excited, the carrier frequency should be checked at least once a week. A crystal controlled transmitter need be checked for frequency only once every few months.

Remote transmitters preferably should be left running continuously as less drift will be experienced operating them this way than if the transmitter is turned on before each broadcast. This is especially true of self-excited transmitters. If the transmitter must be turned off after each broadcast, it should be turned on at least an hour before thenext. This will allow it to warm up to operating temperature and reach its final operating frequency before the program begins. In like manner, any final adjustments of frequency should be made after the transmitter has been running an hour or more so that the drift experienced subsequent to the adjustment wi[illegible] small. A crystal controlled transmitter may be turned off between transmission since the drift experienced while it is warming up will be very slight.

All transmitter and modulator tubes should be checked periodically to be sure that the operation of the transmitter is not impaired because of poor tube cathode emission or other tube failures. Clearly label these tubes to show when it was placed in operation. This will enable the operator to replace tubes before they fail and thus increase the reliability of the operation of the transmitter.

Choosing Proper Operating Frequency

A number of factors must be considered when determining the operating frequency for a wired-radio broadcasting station. The most important consideration is to select a frequency in the lower portion of the Broadcast Band (between 550 and 700 KC). Operation on a frequency in this range is required by the IBS Technical Code because the danger of illegal radiation is least on these frequencies.

It is equally important to choose a channel which is clear of strong signals, and at the same time is not adjacent to a local station. If possible, the wired radio station should be 50 kc. from all local stations, but in congested areas it may be necessary to reduce this margin to 30kc. or even 20 kc. If less than 20 kc. is allowed between a local station and the campus station most radios will not successfully select between them.

To aid in finding the optimum operating frequency a tabulation is given starting on page TI-1111 which lists all domestic and Canadian stations on the broadcast channels between 540 and 700 KC. A search should be made for a channel sufficiently removed from all local signals, as described above, and also not having a useful signal from some distant station, either during the night or day.

At night, when sky wave propagation is important, an apparently clear channel will often prove unsuitable because of a strong signal from a distant station. For this reason, the channels which appear most promising after studying the stations listed starting on TI-1111 should be given a careful listening check. A good communications receiver, with a carrier level meter, should be used for this check. The most promising channels should be checked for several days and nights, readings of signal strength being taken at suffcient intervals to include all the proposed hours of broadcasting.

After studying all possible channels, it may be found that none is suitable in the region between 550 and 700 kc. A frequency lower than 540 kc. should be avoided, of course. However, frequencies as high as 800 kc. may be investigated, the lowest possible one being chosen. Greater care not to radiate excessively must be exercised on these higher operating frequencies and an explanation for the choice and a request for approval should be transmitted to the IBS Technical Manager.

After a careful investigation two or three channels will probably be found which appear suitable. It is often desirable to operate on each of these frequencies, and from the experience thus gained make the final selection. For this purpose the transmitter should be designed for self-excited operation over the range of suitable frequencies. Later, when the best operating frequency has been determined, a crystal accurately ground for that frequency should be purchased, and the transmitter oscilator converted to crystal control. Transmitter H 1108 is provided with a plug-in oscillator coil socket, and the selector switch turned to crystal controlled operation.

Transmitter Stability Requirements

In the range from 540 to 700 kc. there is no broadcast channel on which there is no signal whatsoever. Even a weak signal can cause an annoying heterodyne beat with the signal of a campus transmitter unless the signals are within a few cycles of each other. Conversely, a campus transmitter can cause annoying interference many miles from its legal broadcasting area if it is off the channel frequency.

Paragraph e-4 of the IBS Technical Code requires that "Carrier frequency (shall be) plus or minus 50 cycles per second under all operating conditions." A transmitter operating within these limits on an even 10 kc. broadcast band channel will experience a minimum of mutual interference from other signals on the same channel. To be sure that the limit of 50 cycles is not exceeded under "all operating conditions" the transmitter should stay within five or ten cycles of the nominal channel frequency under normal operating conditions. This allows an adequate margin to accomodate extremes in ambient temperature.

Crystal Control

The most convenient and most economical way to assure that the transmitter stays within the above frequency limits is to employ a crystal-controlled oscillator. An AT cut crystal has a low temperature drift (±0.0001 % per Deg. C) and if accurately ground to the channel frequency used will meet the IBS frequency stability requirements without the need for a crystal oven or a complicated transmitter circuit. If the transmitter is to be exposed to very wide changes in ambient temperature an oven may be needed, but this is not true of transmitters operating in an air temperature range of 60 to 85 degrees F. The transmitter may consist of simply the oscillator and a modulated r.f. amplifier, since a crystal oscillator will give adequate drive for the low power modulated amplifier needed.

Because of the effect of circuit capacity on crystal frequency, most manufacturers will not guarantee better than ±0.01 % calibrating accuracy when the crystal is mounted in a fixed air gap holder such as the Bliley [illegible]-82. Accuracy of this order will not meet the IBS Technical Code requirement of 50 cycles. It is therefore best to order the crystal in a holder

which has a variable air gap, such as the Bliley BC-10, even though such holders are often larger and more expensive.

The frequency of a fixed air gap crystal may be changed slightly by changing the capacity of the circuit in which the crystal is working. The air gap may be slightly increased, as described on page TI-1030, and this results in some shift, but only in the frequency-increasing direction. The crystal must be on the low-frequency side of the desired channel to start with, or no improvement can be made by this means.

A crystal which is too high in frequency to be operated in conventional oscillator circuits may be used in the so-called Pierce oscillator wherein the crystal is connected between the grid and plate of the oscillator tube. The crystal will then oscillate on a slightly lower frequency than before.

If a crystal with low temperature drift characteristics cannot be obtained the crystal holder can be mounted on a large piece of copper to reduce the crystal heating and frequency shift. If such a crystal is placed in an oven with thermostatic control, and the oven adjusted to operate at 35 to 40 degrees C. (well above room temperature), the crystal frequency will be very stable. A temperature should be chosen, of course, which does not appreciably shift the crystal from the desired operating frequency, or reduce the tendency of the crystal to produce oscillations.

Self-excited Oscillators

If a crystal controlled oscillator is not employed, paragraph f-3 of the IBS Technical Code requires that the technical log of the station record "the carrier frequency as measured at daily intervals if the transmitter is... located at the station, or at weekly intervals if the transmitter is... remotely located; by a method approved by the Technical Manager."

To insure the frequency stability required by the Code, a self-excited transmitter must be designed with a buffer stage, and the very best grade components must be used in the oscillator circuit. The oscillator components must be kept away from parts of the transmitter which generate heat, and a negative temperature coefficient capacitor should be included in the oscillator grid tank circuit to compensate for tank capacitor instability due to temperature changes. The correct value of this capacitor must be found by trial-and-error for each combination of transmitter components. The oscillator plate (and also screen) supply should be regulated by means of a V.R. tube. The oscillator components must be rigidly mounted to prevent vibration, and the coils should be wound on ceramic or other stable material. All these precautions greatly increase the cost of the transmitter, and its complexity, over what is required when crystal control is used.

When a transmitter is located where readings must be taken every day, it is permissible to turn the transmitter off when the station is not on the air. Each time the transmitter is turned on, it should be given a warm-up period of at least 30 minutes before checking the frequency.

When a transmitter is located at a remote point, where readings are required only once a week, it should be left operating continuously. This will minimize drifting due to temperature changes. However, this imposes stricter requirements on all the components in the transmitter, since each must be designed for continuous operation; this will increase the cost of the transmitter.

An oscillator which is designed for self-excited operation should be provided with a small variable trimmer capacitor to act as a frequency vernier. Preferably the capacitor should be provided with a geared or vernier dial. The arrangement will permit setting the transmitter on the desired channel with comparative ease.

Tuning Up The Transmitter

General instructions for tuning a transmitter are given in the section which starts on page TI-1031. Further information on checking the frequency of the transmitter is given on the pages starting with TI-1121.

[illegible]

CHECKING THE TRANSMITTER [illegible]

Checking Frequency with a Secondary Standard

The most accurate way to check the transmitter frequency is to employ a secondary standard, such as the James Millen Catalog 90505 Standard. This standard employs a 1000 kc. crystal, which may be adjusted to a primary standard (such as WWV) and multivibrator circuits which generate marker signals every 10, 25, 50, 100, and 1000 kc. over a wide frequency range.

Once the correct marker signal for the broadcast channel to be used has been identified (a good broadcast or communications type receiver is required for this operation) the Secondary Frequency Standard will give a continuous indication of the deviation of the station's transmitter from the absolute channel frequency. The transmitter grid-tank can be retuned during broadcasting if the drift ex- [illegible] nier drive should be built into the transmitter to facilitate this adjustment.

Deviation of the transmitter from the absolute channel frequency will result in a beat which may be heard by listening to the built-in detector in the frequency standard. If this beat is audible, it is [illegible] structed to accurately determine the frequency of the beat. This devi- [illegible] will give the transmitter carrier frequency. A tuning indicator tube can [illegible] possible to estimate the rate at which the eye opens and closes.

Checking the Frequency Against Another Station on the Same Channel

Direct method: Any good broadcast receiver is required for this operation, but it must be so located, and connected to an antenna of such design, that the signal of the local transmitter is of the same magnitude as the signal from the other station on the same channel. This usually means the receiver must be located some distance from the local transmitter. An audio line should be run from the receiver to the local transmitter, so an operator tuning this transmitter can hear the beat caused by his signal with the other signal on the same channel. By this means, the local transmitter may be kept as close to zero beat with the distant station as [illegible].

Indirect method: The same type of adjustment may be made using receiver near the local transmitter if it has a beat frequency oscillator. First the local transmitter is turned off, and the receiver adjusted for zero beat with the distant signal. Then the local transmitter is turned on, and

[illegible] in turn is adjusted for zero beat. If both zero beat operations are carefully performed, and if the receiver is stable, the final adjustment of the local transmitter will place its frequency within 50 cycles of the distant one. A tuning indicator connected to the a.v.c. circuit of the receiver will aid in determining the exact point of the zero beat.

If the receiver does not drift, it can be used as a continuous monitor of the local transmitter's frequency. However, since most receivers do drift, the indirect method is limited in use to times when the local transmitter may be turned off, to permit tuning the receiver to zero beat with the distant station.

Refinements In The Above Methods

From the above discussion it is apparent that transmitter drift is a serious problem. A transmitter designed for minimum drift may still exhibit an appreciable tendency to drift when it is first turned on. Therefore, carrier frequency adjustments should not be made during this warm-up time, nor should a program be carried over a self-excited transmitter during this interval. It is best to arrange a time switch to turn the transmitter on at least [illegible] minutes before the day's broadcasting is scheduled, and to check the transmitter frequency and adjust it, if necessary, 15 minutes before the program begins. During the warm-up and tuning adjustment periods the transmitter should be disconnected from the usual r.f. load and connected to an equivalent dummy load. This will prevent broadcasting a signal which is more than 50 cycles away from the nominal channel frequency. Care should be taken to re-connect the transmitter to the r.f. line before beginning the scheduled broadcast! Indicator lights to indicate the position of the r.f. transfer switch will minimize the danger of forgetting to connect the transmitter to the transmission lines.

TRANSMITTER OSCILLATOR DESIGN

Crystal Controlled Oscillators

A single stage using a receiving type pentode as a crystal controlled oscillator is sufficient to drive the 5 or 10 watt power amplifiers found in wired radio applications. Since it is crystal controlled changes in loading on the oscillator caused by changing operating conditions in the power amplifier will not result in too great instability. Such a circuit is used in transmitter E1108.

If the best operating frequency for the station has not been selected, this oscillator may be operated self-excited. This should be considered only a temporary expedient. As soon as the channel for continuous operation has been decided upon, a crystal should be purchased for this frequency, and used. E1108 shows an arrangement which permits readily either a crystal or grid coil. A crystal holder having a variable air gap should be used (see page TI-1103) and these are not always of the plug-in type.

It is advisable to regulate the supply for this single stage oscillator using an OD3/VR150 glow tube. Note that both screen and plate supply for this stage should be regulated.

If it is desired to add an intermediate power amplifier stage without adding another tube, the RF section of transmitter E1095 can be modified to do the job. The only disadvantage is that the output section of the 6N7 must be neutralized, which is not the case when a pentode is used as an intermediate power amplifier. If this portion of the circuit on E1095 is used as a driver, the audio circuits and the 6J5 modulator tube are obviously not required. A plate voltage up to 250 volts may be applied to the output section of the 6N7 if required to obtain adequate drive for the power amplifier. When using the circuit in this manner it may prove advantageous to reduce the tuning capacity in the output tank circuit to about .00035 mfd. and increase the inductance of the tank coil correspondingly. This change in the tank circuit constants will result in greater r.f. voltage being available to drive the following stage. A similar oscillator-buffer stage is shown on E1123.

Self-excited Oscillators

If a transmitter is designed primarily for self-excited operation greater precautions must be taken. A buffer stage is necessary. Two receiving type pentodes may be used; refer to E1081. The permeability-tuned oscillator grid coil shown adds to the stability of the oscillator. A shielded I.F. transformer may be used. If a 465 kc. IF transformer is used, it can be modified to have the desired inductance of 0.05 millihenries.

The buffer plate tank should be tuned to the second harmonic of the oscillator, to give the correct drive to the power amplifier. Doubling [illegible] reduces the coupling-back effect on the oscillator, resulting in greater stability.

One disadvantage of this oscillator is that the third harmonic of the oscillator is only $1\frac{1}{2}$ times the output frequency of the transmitter [illegible] as an annoying harmonic in the broadcast band.

Precautions must be taken to be sure all parts are firmly mounted. A regulated high voltage supply for the oscillator is a necessity. If stability from temperature change effects is not good enough, negative temperature coefficient capacitors may be added to the oscillator grid tank until tests indicate the stability is satisfactory.

In general, the added work and components required to make a stable oscillator transmitter [illegible] economical [illegible] crystal control [illegible] a simpler tube and circuit arrangement.

[illegible]

[illegible]fer amplifiers in transmitters are used to isolate the oscillator [illegible] used to double or triple the transmitter frequency. Usually in small [illegible] stage on anything but the same frequency as the oscillator.

The buffer amplifier should be designed as a Class C RF amplifier; thus the same considerations applying to the grid bias voltage of power amplifier [illegible] ated Class A in an effort to reduce loading on the oscillator stage, as unless the buffer amplifier is operating under true Class C conditions, carrier hum generated in the oscillator will be amplified in the buffer stage. Triode buffer stages must be equalized the same as triode operated power amplifiers.

The buffer tank circuit can be designed with less capacity and more inductance than the tank circuit of a modulated rf stage. It is common practice in the buffer amplifiers of small transmitters to employ a standard broadcast band variable capacitor and coil. The coil may be obtained in a shielded can and this type is advisable as it will reduce radiation from the buffer stage and will increase the mechanical stability of the transmitter. A standard plug-in coil form may be used, provided the transmitter is well shielded to prevent radiation from this coil.

Coupling between the buffer plate and power amplifier grid is usually accomplished through a small coupling capacitor, which can be variable to permit a fine adjustment of grid current in the final amplifier stage.

Buffer amplifiers are used in transmitters T1081, T1138 and T1123

MODULATED RF AMPLIFIER DESIGN

Power Level

Experience gained by IRS during the past six years indicated that the large blocks of modulated r.f. power are seldom required. An r.f. power level of five watts will adequately cover a campus of unlimited size, provided an efficient r.f. transmission system has been installed.

More power and a less efficient transmission system lead only to grief, as excessive radiation results together with the likelihood of difficulty with the Federal Communications Commission. The solution which is always arrived at is to improve the transmission system, and then it is found necessary to absorb all but a few watts of the transmitter output in a dummy load, such as a lamp bulb.

Need for Good Design

One reason often advanced for using a higher power transmitter is that better quality will result. This contention is advanced because of previous experience with small transmitters which have not performed well because of inadequate design. The same design principles hold for a modulated Class C r.f. amplifier rated 10 watts input which hold for one rated 25 to 100 watts. Too often small transmitters are designed on a minimum cost basis, and good design principles are disregarded.

Choice of Circuit

A plate modulated Class C amplifier is the best type to use when developing a modulated carrier at low power levels. Grid modulation can never be designed for as low distortion, and the additional audio power required for plate modulation involves no great extra expense at low power levels.

A modulated triode may be employed, but the additional complication of neutralizing the stage can be avoided by using a pentode. At broadcast band frequencies elaborate shielding is not required to build a pentode amplifier stage which requires no neutralization.

Choice of Tube

Of the pentode r.f. amplifier tubes available, the 1613 is the one suitable for power levels of ten watts input, and below. This tube is the same as the 6F6 receiving type tube, and the 42 and 2A5 receiving type tubes may be substituted for the 1613 by employing a six terminal socket, and a 2.5 volt heater supply in the case of the 2A5.

10/2/47

Operating data for this tube follows:

1613 (6F6) Pentode

Plate Modulated R.F. Amplifier - Class C.

Typical Operation

D-c Plate Voltage	275 V.
D-c Screen Voltage	200 V. - 10,000 ohms.
D-c Grid Voltage	-35 V. - 12,600 ohms.
Peak R.F. Grid Voltage	65 V.
D-c Plate Current	42 ma.
D-c Screen Current	10 ma.
D-c Grid Current	2.8 ma. approx.
Driving Power	.16 Watt approx.
Power Output	6.0 Watts approx.

Circuit

The circuit for this stage is shown in transmitter H1122, Parallel feed to the plate is indicated. This is helpful in that the tank capacitor need not be insulated from the chassis. If a capacitor with insulated frame is available, series feed may be used. Series feed should not be attempted with a grounded tank capacitor because the plate by-pass capacitor, to be large enough to permit [illegible] the tank, will by-pass high frequency audio power from the modulator.

Grid Circuit and Drive

Drive adequate to give 2.8 ma. d-c grid current is required. The grid current jack should always be included in order to check this current. A [illegible] (6C5) [illegible] crystal or electron coupled oscillator will be suitable. For maximum self-excited stability, a 6N7 oscillator and buffer should be considered. Refer to TI-1151. A coupling capacitor from 25 to 50 mmmf. is sufficient. A greater value may reduce the drive.

Plate and Screen Circuits

The plate and screen circuits are fed from a common voltage supply, which feeds through the modulator. It is important to modulate both the plate and the screen for linear operation. The plate current meter jack is arranged to read the sum of the plate and screen currents, so at resonance the current dip will not be as pronounced as in a triode amplifier stage.

Tank Circuit Design

The design of the tank circuit is probably the most important phase in the design of a modulated C r.f. amplifier. A [illegible] capacitor and coil combination should not be used, as the L-C ratio is incorrect for linear performance under modulation.

The tank circuit must present the proper r.f. load impedance to the Class C amplifier tube, and also should have a loaded Q of about 12 so as to attenuate the higher frequency harmonics during modulation. Calculations based on class C amplifier theory indicate the correct r.f. load impedance for the 1613 operating under the conditions specified earlier is approximately 3000 ohms.

The tank coil should have a reactance of 3000/12 or 250 ohms at the frequency to which the tank is to be tuned. This is an inductance of 62 microhenries at 640 kc. (Calculated as 250/2x3.14x640,000 or L=X1/2pi.f.) The tank capacitor to go with this would then be rated about .001 mf. A 750 mmf. fixed capacitor and 365 mmf. variable capacitor in parallel will provide adequate tuning range.

Modulator Impedance and Power

The impedance of the class C amplifier presented to the modulator is the class C amplifier supply voltage divided by the total current as read on the plate meter. For the conditions given earlier, this impedance is 275/0.052, or 5,300 ohms. The secondary of the modulation transformer should be adjusted to match the modulator tubes to this impedance.

The audio power required of the modulator is approximately one-half the power input to the class C stage. This power input is the product of plate supply voltage and the sum of the plate and screen currents: in this case, 275 x 0.052 = 14.2 watts. Thus, 7.1 watts of audio power is needed. Considering the losses in the modulation transformer, and the desire for low audio distortion, an amplifier normally rated at least 10 watts should be used. Amplifier HI105 is therefore suitable.

Reduced Power Operation

This class C stage may be operated with reduced plate supply voltages if it is desired to have less r.f. power output. The grid and tank circuit constants given in this paper will be satisfactory for supply voltages between 200 and 275 volts. At reduced voltage the plate and screen currents will be less. It will therefore be necessary to recalculate the modulator power required, and the correct load impedance to which the modulator must be matched. Such a transmitter is shown on E1122.

A single 1613 may be used to modulate this stage, using a common modulation choke for coupling. Such a transmitter is shown on E1108.

[illegible]

The modulator for a plate modulated transmitter is an audio amplifier having sufficient power at low distortion to modulate the stage 100 per cent. The amplifiers shown on H1098, H1102, and H1105 may be used as modulators.

The power required for 100 per cent modulation of a class C r.f. amplifier stage is half the power input to the stage. The modulator should be designed having a liberal margin of 15 to 25% to take into account losses in the modulation transformer. If the r.f. power amplifier stage is a pentode, the screen of this tube should be modulated through a dropping resistor and the screen current should be added to the plate current when calculating the power input to the stage. The power input then becomes the product of the sum of the screen and plate currents (in amperes) times the plate supply voltage.

The modulator must be adjusted to operate into the impedance presented to it by the class C amplifier stage. This impedance is found by dividing the power supply voltage applied to the class C stage by the total plate and screen currents in amperes. The answer is expressed in ohms. Modulation transformers are available having a wide selection of taps on the secondary to permit properly matching the modulator tube to the load presented by the usual class C amplifiers encountered in practice.

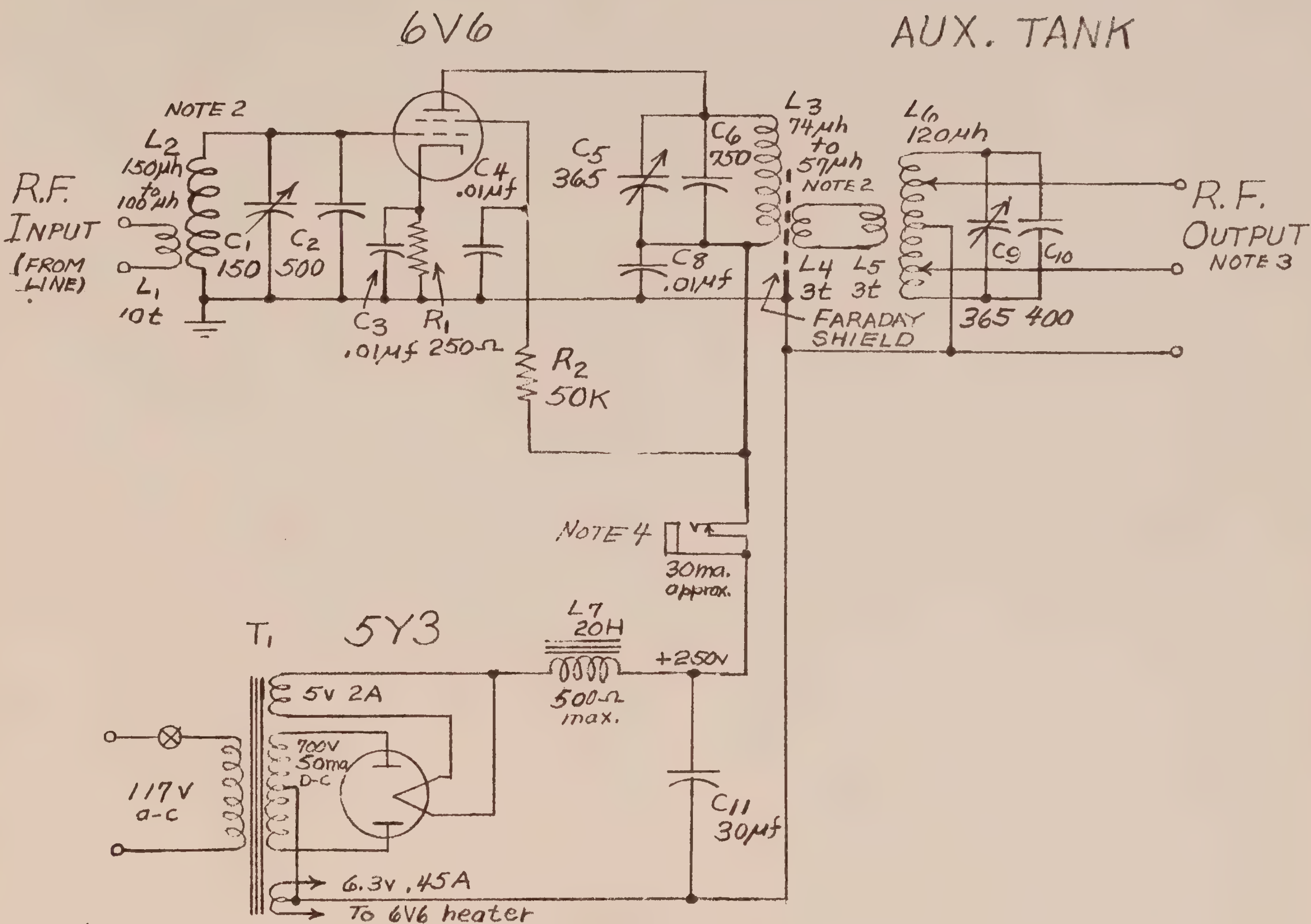
The modulation transformer selected should be liberally rated to prevent poor low frequency response. This is especially true if modulation transformers designed primarily for amateur service are used, since in communications low frequency response is not important. It is also wise to keep direct current out of the secondary winding of the modulation transformer. This is done by means of a coupling capacitor and modulation choke as shown on diagram H11[illegible]. If this is not done, the direct current flowing in the secondary of the modulation transformer may saturate the core, again resulting in poor low frequency response. The direct current flowing in the primary winding of the modulation transformer is no problem so long as the modulated stage is push-pull and the tube currents of the output tubes are nearly the same.

LINEAR RF AMPLIFIER DESIGN

Linear r.f. amplifiers are designed to amplify an r.f. signal without introducing wave-form distortion. For this reason, a class A or class B amplifier circuit must be used rather than the class C circuits used in buffer and power amplifiers in transmitters. Design of such r.f. amplifiers is similar to audio amplifier designs, with the exception that in place of resistors or audio transformers for loads, tuned r.f. circuits are used. Also, it is not feasible to employ inverse feed-back in linear r.f. amplifiers, as is often done in audio amplifiers.

Linear r.f. amplifiers are usually used at the ends of long r.f. transmission lines to boost the r.f. power on these lines to an amount sufficient for the area to be covered.

Amplifier E100 is a unit which can be used to boost the signal at the end of 1000 to 2000 foot line and will have sufficient power to cover three or four dwellings, such as fraternity houses. More gain can be obtained by adding a receiving type pentode (6SK7 or similar) ahead of the 6V6 and more power output can be obtained by using a 6L6 or 807 in place of the 6V6. Where very large amounts of power are needed, a push-pull class B r.f. amplifier may be used.



NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROMICROFARDS UNLESS SHOWN OTHERWISE.
2) INDUCTANCE VALUES FOR L_2 AND L_3 GIVEN FOR 540KC. AND 700KC. INTERPOLATE FOR OTHER CHANNELS.
3) ADJUST TAPS ON L_6 TO MATCH LOAD
4) AMPLIFIER OPERATES CLASS A. OBSERVE PLATE CIRCUIT METER WHEN ADJUSTING C_1, C_5 AND C_9.

TITLE R. F. LINEAR AMPLIFIER (WITH AUXILIARY TANK)

FILE REF. T15.16

BEGUN BY DWBorst 1942	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1004	CM DL R
FINISHED BY RETRACED Nov 2, 1947 DWBorst			PRINTS TO
REVISED: 1 Jan 24, 1945 2 Nov 2, 1947			

SPEECH INPUT EQUIPMENT STANDARDS REQUIRED BY THE IBS

The following paragraphs of the IBS Technical Code apply specifically to speech input equipment. They give minimum requirements which must be met when designing such equipment.

Excerpts from Technical Code

"Each Member (group) which operates or participates in the operation of a system disseminating programs through the use of one or more carrier current devices shall adhere to the following technical regulations and standards of good engineering practice:

e. Each (programming) system shall employ the following studio facilities:

1. Two or more independently attenuated microphone channels and microphones;

2. Two separately attenuated phonograph channels, or a single attenuated channel employing instantaneous switching between two phonograph pickups;

3. One separately attenuated input for one or more remote lines, which may be combined by means of instantaneous switches with one phonograph channel input, if two separately attenuated phonograph channels are provided;

4. Two 78 r.p.m. turntables and lateral (cut) pickups and one 33 1/3 r.p.m. turntable and lateral (cut) pickup; Latter may be combined with one 78 r.p.m. unit;

5. Loudspeaker monitoring in all separate control rooms, and earphone monitoring in all control locations;

6. Volume indicator on program output.

f. Each (programming) system shall meet the following standards of performance:

2. Distortion introduced after microphone or phonograph input; less than 7.5% R.M.S. at 95% modulation measured at (either) 1000 or 400 cycles per second.

3. Overall frequency response of system after microphone and phonograph inputs; flat within plus or minus 2 db of (either) the 400 or 1000 cycle response from 100 to 5000 cycles per second.

5. Noise and hum introduced after microphone 40 db. or more below 95% modulation.

The above facilites, listed in section e., are the bare minimum requirements for program production. Pages TI5001 through TI5007 describes the facilities needed to produce a wide variety of programs with ease and skill. It will be recognized that the minimum studio equipment required of IBS Member groups is essentially the basic equipment needed for Master Control, with the exception that in Master Control remote programs, and programs from studios, do not pass through the Master Control mixer, but are routed by the channel amplifier input selector switches.

The audio distortion and noise requirements, listed in section f., are again a minimum requirement. Better standards are met by most standard broadcast stations. The requirements for FM broadcasting stations are even more stringent. This should be remembered if it is contemplated to add educational FM broadcasting facilities at some later date. The minimum requirements for standard broadcast band stations and for FM broadcasting stations are formulated by the Federal Communications Commission, and may be obtained by writing this governmental agency in Washington, D.C.

Engineering Note
Number 2

March 25, 1947

[illegible]

These remarks could be filed in almost any section of this Data Book because almost any piece of apparatus will perform better if it is properly grounded. In many cases a fair ground may appear satisfactory, but when high gain audio equipment is involved the best ground is often only good enough. Every so often reports circulate concerning troublesome r.f. pickup in microphone pre-amplifiers and similar ills. Look into your ground system for one possible cause of such difficulties.

A good ground is a short, heavy copper wire run to some well-grounded structure. A cold water pipe may do if it goes directly into the earth; never trust a steam pipe. Often a three or four foot rod driven into the ground the shortest possible distance from the equipment to be grounded is best. Impregnating the earth around this rod with a brine solution is a good idea.

The staff at WSRN went all out when they needed a good ground. David Linton, formerly Manager of the station, describes it by saying: "We got an old lightening rod cable, connected to a large iron plate which was deeply buried in a pit of rock salt. From this we ran a braided copper cable 1/2 inch in diameter into the control room. That is our station ground. It works."

David W. Borst

Technical Manager

Engineering Notes are issued from time to time by the Technical Department, Intercollegiate Broadcasting System, [illegible] Ave., Schenectady 2, N. Y.

It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for ready future reference.

Technical Department [illegible]

Engineering Note
Number 4

March 25, 1947

Panel Labels

I recently hit on a plan of using photographically reproduced panel labels in order to get them white-on-black, which seems best. I typed them on a sheet of tracing paper with carbon backing, and then made a contact print on high-contrast paper (Koda Bromide F4 will do). The results were good. Careful typing, to give uniform weight of line, is important.

The console at WKCR is now equipped with these labels. The method is a cheap and quick way of making a number of labels, for anyone who has access to a darkroom.

Paul F. Yergin

Business Manager

Engineering Notes are issued from time to time by the Technical Department, Intercollegiate Broadcasting System, 700 Sanders Ave., Schenectady 2, N.Y.

It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for handy future reference.

Technical Department Engineering File Number T15.21.

[illegible]
Number 7

March 30, 1947

THE USE OF PUBLIC ADDRESS AMPLIFIERS FOR PROGRAM INPUT EQUIPMENT

Public address amplifiers partially meet the requirements of program input equipment, and so sometimes are used when a campus station is first constructed. Often a limited budget coupled with a small technical staff may make the use of a public address amplifier as the studio mixer attractive. If this is the case, it should be recognized that the studio facilities made possible in this way are far from being what they should, and the public address amplifier should be retired as soon as possible.

Public Address Amplifier Deficiencies

The principal short comings found in the average low cost public address amplifier when it is used as a program input amplifier are:

1) Too few input channels.
2) Microphone inputs are high impedance.
3) Microphone channels have insufficient gain.
4) No interlock circuits or channel off-on switches.
5) No volume indicator.
6) No earphone monitor.
7) Excessive distortion.

By modifying the amplifier some of these deficiencies may be partially overcome, but such modifications must be simple and easily [illegible] or it soon becomes more economical to build program input equipment which will givethe results desired.

In case no other alternative is possible the following data will prove useful when working a public address amplifier into the station layout.

Selecting The Amplifier

In order to obtain an amplifier which will provide the minimum number of inputs required in the IBS Technical Code (two microphone channels and two phonograph channels) it is usually necessary to select an amplifier with a power output rating of 20 or 30 watts. This amount of audio power is not needed and so money must be invested in unnecessary equipment capacity. Care must be taken not to select an amplifier having two phonograph inputs which feed into a single channel through a fader type control. It must be possible to mix the two phonographs as well as the two microphones.

Applying the Amplifier Properly

The objection of high impedance microphone circuits can be partially overcome if microphones having a universal output (provided with an output impedance selector switch) are used. Later, when low impedance microphone circuits are installed, the same microphones can be used by turning the selector switch to the correct impedance.

If the microphone circuits have too little gain, program production work will be hampered because the performers will have to work too close to the micrphones. There is no way to easily correct for this deficiency.

The least expensive way to add a speaker interlock circuit is to replace the microphone volume controls with controls having switches attached. These switches must be closed only when the control is in the extreme left position (the usual off position). By wiring the switch contacts of all microphone gain controls in series, and then connecting them in series with the monitor speaker voice coil, monitor speaker will be turned off whenever a microphone gain is turned up. It is not economical to install channel off-on switches, or make other more extensive changes in the amplifier wiring.

The public address amplifier chosen may have a volume indicator but chances are great that it will not. If it does, probably it will not be the type preferred for broadcast purposes, the VU meter. The only procedure, then, is to purchase a VU meter and connect it to the 500 or 600 ohm output of the amplifier through a suitable pad. More will be said about this in a later paragraph.

A headset can be bridged across the 500 to 600 ohm output of the amplifier through a resistor selected to give the desired volume level.

Excessive distortion can be overcome by operating the amplifier below its rated power output. Usually the amplifier will have no master gain control, so the only alternative is to operate the gain controls over a small percentage of their total range. For this reason, and also for the reason that operating the amplifier much below its rating will increase its apparent noise and hum level, the difficulty of excessive distortion can only partially be overcome.

Using the Power Output of the Amplifier

As mentioned previously, the amplifier chosen will probably have an output rating of 20 or 30 watts. To reduce distortion to a reasonable level it will probably be necessary to operate the amplifier at 10 or 15 watts. This is still more power than needed by the average station; either for a monitor speaker, or to modulate a transmitter, the two most common uses for this amount of power. The difference between the power available and the power required must be absorbed in resistance pad. Data for such a pad will be found in texts on communication engineering.

If the amplifier is to be used to modulate a transmitter, the 500 or 600 ohm output should be used (whichever is available). The

should be passed through a pad to reduce it to the level required for 100 percent modulation, and then the transmitter should be modulated through a transformer designed to match the amplifier output impedance to the transmitter modulated stage plate circuit impedance. The VU meter should bridge the input of the modulation transformer through a suitable 3900 ohm pad designed to attenuate the 100 percent modulation level to plus 14 dbm. (This includes a 10 db margin to prevent over-modulation on sudden peaks.) Referring to page [illegible], Fig. [illegible] is a schematic diagram for a representative circuit worked out for a 30 watt amplifier operated at 15 watts and being used to modulate a 6 watt transmitter. It will be noted that the pad changes the circuit impedance from 500 to [illegible] ohms. This is desirable for proper operation of the VU meter. Circuit constants are given.

The amplifier may be used to operate the monitor speaker, if this be more desirable. In this case, the amplifier should be adjusted to have an output impedance close to the loudspeaker voice coil impedance. A pad at this impedance level should be constructed to reduce the amplifier power to one watt at the speaker. The interlock circuit should be arranged to open the speaker voice coil if the speaker is to be in the same room with the microphone. The VU meter may be connected to the 500 ohm output of the amplifier and a pad constructed to reduce the signal in this circuit to the proper level (plus 4 vu). The modulator input should be arranged to bridge the 500 ohm output of the amplifier. A 500 ohm load should not be connected to the amplifier since the amplifier is already loaded into the pad at voice-coil impedance.

Conclusion

The changes indicated above are not difficult, and will make it possible to temporarily use a public address amplifier as a program input amplifier. As soon as possible, this amplifier should be replaced with one designed for broadcast work. At this time, the public address amplifier will be found suitable for public address work without the need for making any further changes. If the public address amplifier was used to modulate the transmitter, a new modulator will have to be built at the time the new program input equipment is installed.

Reference:

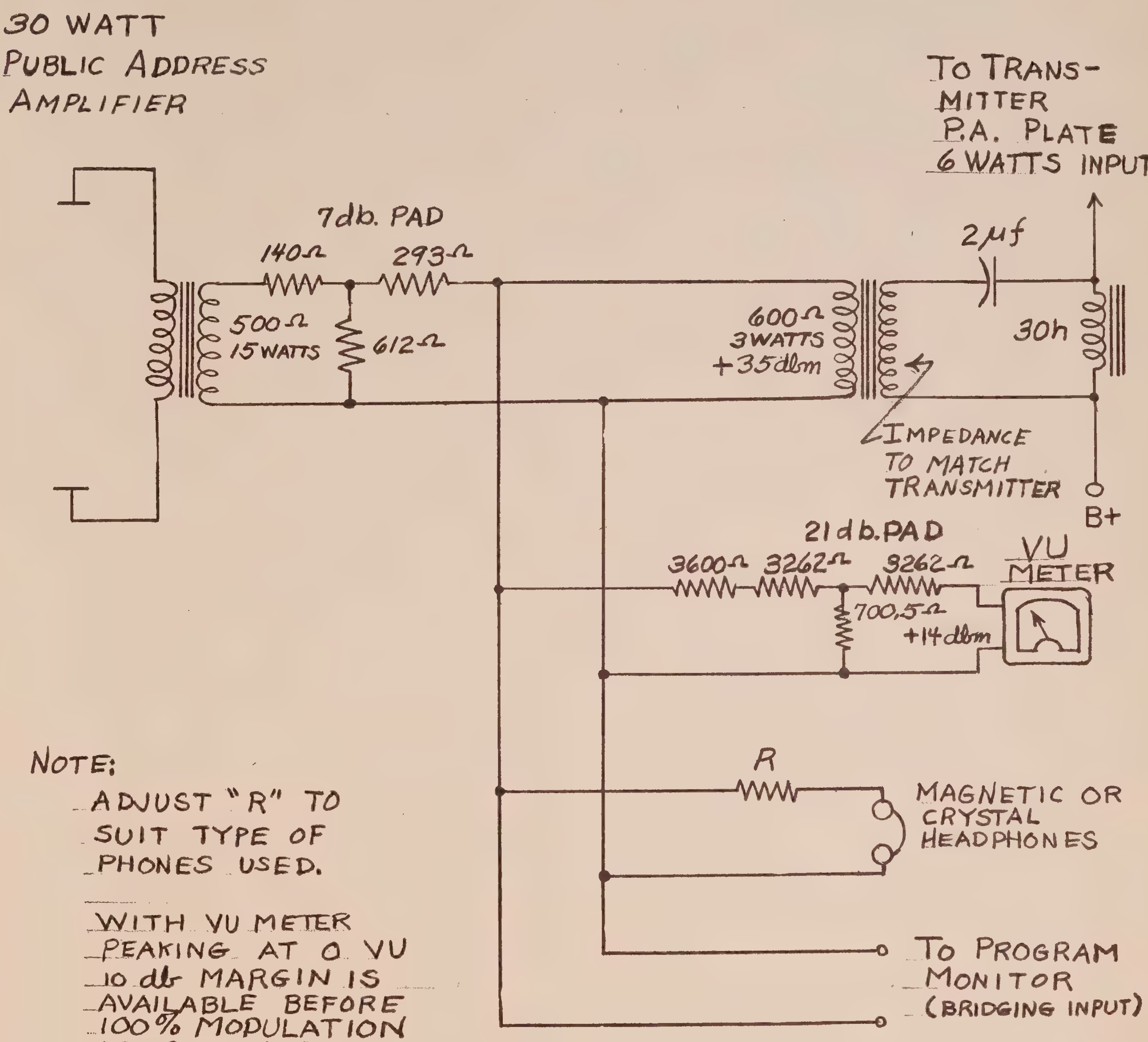
Radio Engineering Handbook HENNEY Edition III, page [illegible]. (Gives data on resistance pads.)

Engineering Notes are issued from time to time by the Technical Department, Intercollegiate Broadcasting System, 706 [illegible] Ave., Schenectady 2, N.Y.

It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for handy future reference.

Technical Department Engineering File Number [illegible]

H1106



NOTE:

ADJUST "R" TO SUIT TYPE OF PHONES USED.

WITH VU METER PEAKING AT 0 VU 10 db MARGIN IS AVAILABLE BEFORE 100% MODULATION IS REACHED.

TITLE OUTPUT CIRCUIT FOR PROGRAM INPUT AMPLIFIER

FILE REF: T15.34

BEGUN BY D.W. Bost Oct 6, 1946 FINISHED BY D.W. Bost Oct 6, 1946	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1106		CM-HT PY DL R PRINTS TO
REVISED: ① Feb 22, 1947				

T152 7-7-45

[illegible]

[illegible]

[illegible]

POWER RATINGS OF AUDIO AMPLIFIERS

When designing audio equipment for broadcast use, it is important to have reserve power available to handle peak levels without excessive distortion. A margin of 10 db has recently been accepted as an industry standard.

Translated into power levels, this requirement means that amplifiers for such purposes as feeding audio lines should be good for ten times their output as read on a VU meter without distortion. Tests at this ten-times level are conducted with a sine-wave signal, of course. This same rule holds for power amplifiers, such as monitors.

In transmitter design, the requirement for reserve power means that the transmitter must be operated 10 db below 100 percent modulation under normal conditions so that peaks will not cause over-modulation. Conversely, at the ten-times normal power level, the transmitter shoud be modulated exactly 100 percent. The modulator is required to deliver, with no distortion, the power needed for 100 per cent modulation. For a plate modulated Class C RF stage the modulator audio power output should be one half the product of plate (plus screen) current in amperes and the plate voltage in volts.

When designing an amplifier to feed a telephone circuit the requirement is a minimum level on the telephone lines of plus 8 VU. This level must be read on a VU meter for anything but sine wave steady state conditions. Under these latter conditions plus 8 VU in a 600 ohm circuit is 0.006 watts. Applying the 10 db margin rule as given above, the amplifier should be good for 0.06 watts.

If the amplifier is transformer coupled to the line, a 6 db isolating pad is desirable between the amplifier and the line. This pad insures that the load reflected on the plates of the output tubes is correct in spite of the fact that the telephone line may not appear to be 600 ohms at all frequencies. To produce 0.06 watts in the line (peak) the amplifier must therefore produce 0.24 watts at no distortion. A 6SN7 in push-pull, or a pair of 6J5's, will produce this power at less than 0.5% rms harmonic distortion, provided a good output transformer is used.

David [illegible]
[illegible]

[illegible]

[illegible] Technical Department, [illegible] 2, N.Y.

It is suggested that a copy be bound in the CBS Technical Data Book at the page indicated for handy future reference.

Technical Department Engineering File Number [illegible]

[illegible]

Engineering Note
Number 15

April 11, 1948

Audio Amplifier Circuits

Immediately following page TI-2057 in the third edition of the IBS Technical Data Book you will find the schematic diagrams of a number of audio amplifiers. This Engineering Note is intended to explain some of the uses to which these amplifiers may be put.

H1090 Channel Amplifier

This unit was designed for service as a channel or isolation amplifier in master control equipments. The use of push-pull cathode followers eliminates the need for an output transformer; the use of a cathode-coupled phase-inverter eliminates the need for a input transformer. This results in a considerable cost savings, which more than offsets the somewhat greater plate current requirements compared with a more conventional amplifier like H1111*. Also, a power supply with a special tap to permit running B- 40 volts below ground is recommended. Such a supply is H1100. The design of this unit is discussed in the article "Gain Chart for Cathode Follower" by Gladden Houck, which appears in <u>Tele-Tech</u> for August, 1947, on page 54. For reprints ask for IBS Form T173. The unit has been or is being used successfully at [illegible], [illegible] and WRUC. Input gain control circuits are shown on H1120; circuit "A" is preferred. Harmonic and intermodulation distortion are low.

H1120 Input Circuits for Amplifier H1090

Figure A may be used with both H1090 and H1099 to provide an input gain control. Figure B is recommended only as a temporary expedient.

H1100 Power Supply for Two H1090 Amplifiers

Two H1090 or two amplifiers may be fed from this supply. It is conventional except for the fact that B- is 40 volts below ground. Note 1 is a good hint in connection with all power supplies, if the d-c voltage does not come out just right.

H1099 Booster Amplifier

This is a companion unit to H1090 and is to be used when 25 db. or so boost is required, such as when feeding a remote broadcast line into master control after equalizing it. Use 1120 "A" input gain control.

H1111 Channel or Booster Amplifier

This is a more conventional counterpart of H1090 and H1099. The gain control is a high impedance unit following the input

* Drawing H1111 does not appear in the Technical Data Book. Prints may be ordered from IBS Engineering Dept.

transformer in each case and so more difficult to wire in than is the case with H1090 and H1099. These units are in use at [illegible].

H1038 Power Amplifier Data

This data for 6F6, 6V6 and 6L6 amplifiers should prove useful in designing monitor and modulator amplifiers, although H1102 and H1105 are designs of complete amplifiers (less power supply) which may save you some work.

H1102 Power Amplifier

This unit makes a nice amplifier to drive one monitor loud speaker or to modulate a small transmitter such as H1122. However, it may be that the rating is optomistic; $3\frac{1}{2}$% distortion as shown on H1038 may be more nearly correct. If lower distortion is desired, or up to 10 watts is required, 6L6's may be substituted for the 6V6's simply by changing R_{14} to 125 ohms, 10 watts, and using a power supply rated at 164 ma. or greater. The output transformer should be selected to give 5000 ohms plate-to-plate impedance.

H1105 Power Amplifier

The driver shown on this schematic is somewhat better than on H1102 and so the 6L6's can be rated 12 watts or 2%. The greater gain that results from the extra stage is bothersome if this amplifier is used as a monitor; you can't turn the gain down far enough! H1105 is recommended more for modulator service where full power output is required. If you wish 6L6's in your monitor amplifiers use H1102 modified as described under H1102, above.

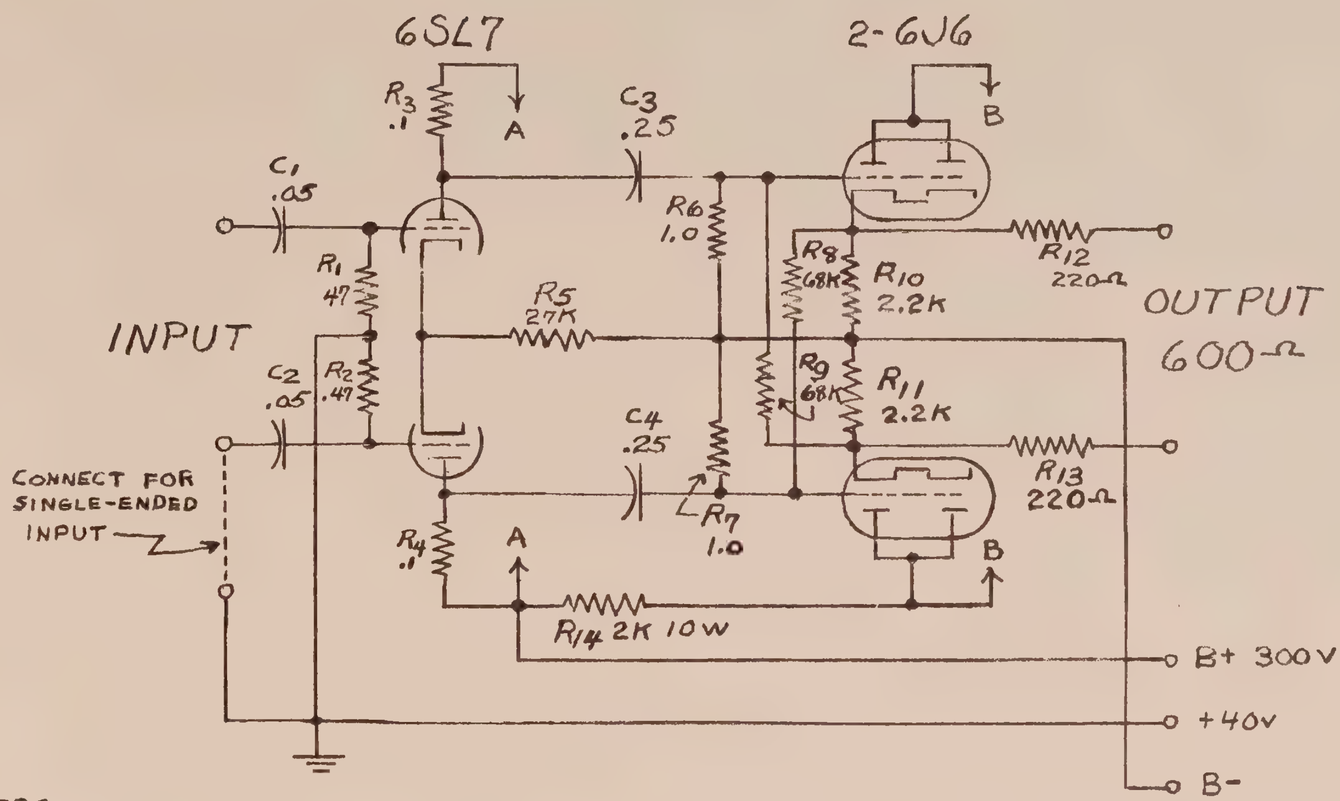
David W. Borst

Engineering Notes are issued from time to time by the Engineering Department, Intercollegiate Broadcasting System, WKCR Hamilton Annex, Columbia U., New York 27, N.Y.

It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for handy future reference.

If your station does not have the third Edition of the Technical Data Book write us about it.

Engineering Department File Number T15.20.



NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROFARADS UNLESS SHOWN OTHERWISE.
2) SIMILAR TO H1062-A
3) FOR INPUT AND GAIN CONTROL CIRCUITS REFER TO H1120.

PERFORMANCE DATA

OUTPUT LEVEL	+14 dbm.
HARMONIC DISTORTION	0.5% R.M.S.
VOLTAGE GAIN	16 db.
PLATE CURRENT	42 ma. (at 300v. d-c)
HEATER CURRENT	1.2A (at 6.3v a-c.)

TITLE CHANNEL AMPLIFIER

FILE REF: T15.25

BEGUN BY D.W. Borst May 22, 1946 FINISHED BY RETRACED D.W. Borst Feb 25, 1947	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1090	RK PY DL R PRINTS TO
REVISED: 1 Sept 17, 1946 2 Feb 25, 1947 3 Sept 2, 1947			

BRIDGING INPUT

FOR CHANNEL AMPLIFIER SERVICE

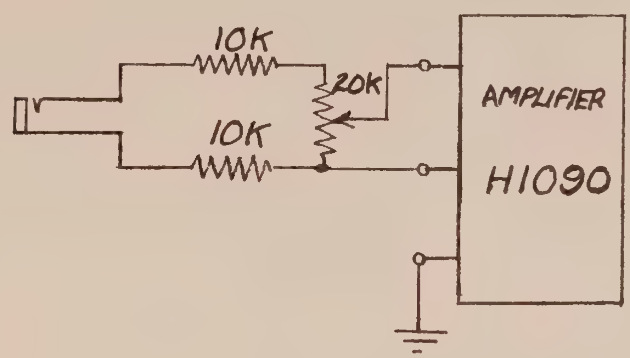


FIG. A

LOSS THROUGH CIRCUIT 6db.

MATCHING INPUT

FOR BOOSTER AMPLIFIER SERVICE

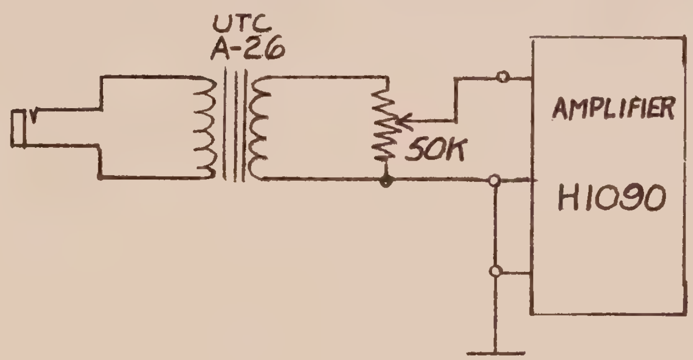


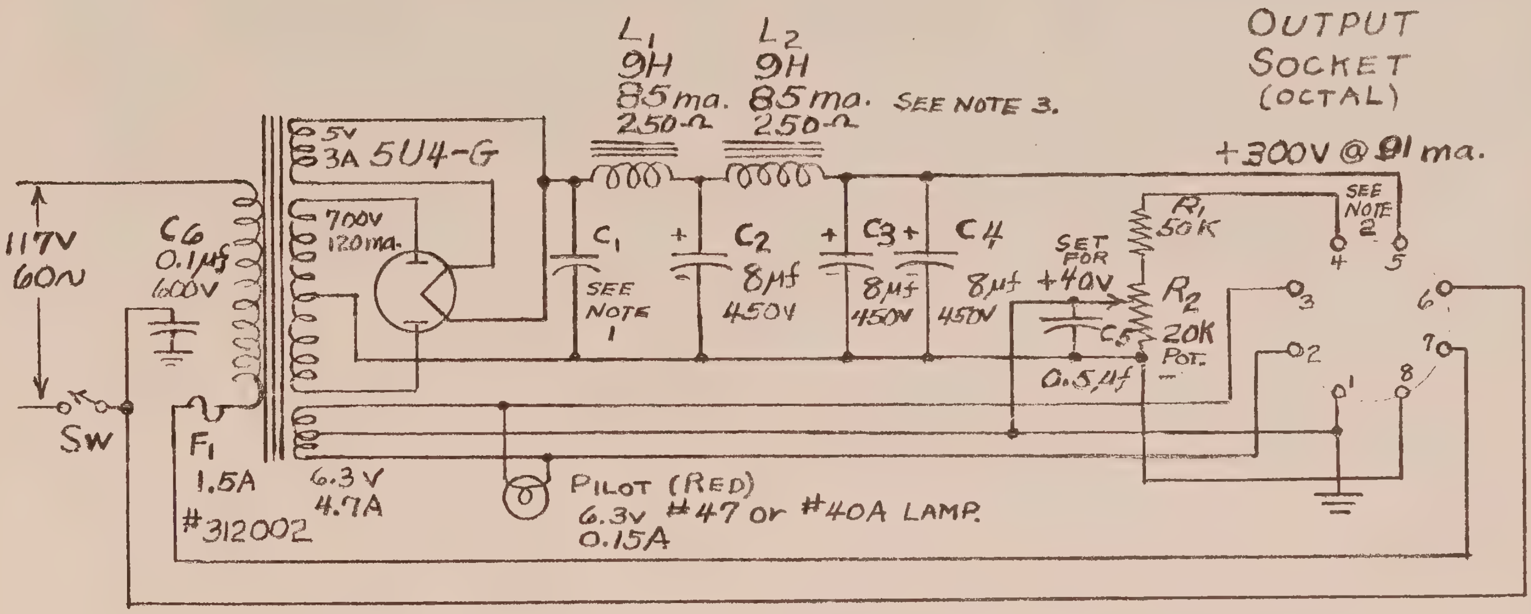
FIG. B

GAIN THROUGH CIRCUIT 20 db.

TITLE INPUT CIRCUITS FOR AMPLIFIER H1090

FILE REF.: T15.34

BEGUN BY D W Borst Feb 25, 1947	INTERCOLLEGIATE BROADCASTING	H1120	RK-HT
FINISHED BY D W Borst Feb 27, 1947	SYSTEM TECHNICAL DEPT.		PY
REVISED:			DL
			R
			PRINTS TO



NOTES:

1) ADJUST VALUE OF C_1 TO GIVE RATED D-C OUTPUT VOLTAGE APPROX VALUE - 1µf., 600V PAPER.
2) PROVIDE JUMPER BETWEEN PINS #4 AND #5 IN POWER CABLE TO H1090 AMPLIFIERS. TO CONVERT SUPPLY TO CONVENTIONAL TYPE OMIT JUMPER AND CONNECT B- TO GROUND.
3) L_1 AND L_2 SHOULD BE RATED 100 MA.

TITLE POWER SUPPLY FOR TWO H1090 AMPLIFIERS

FILE REF.: T15.92

BEGUN BY D.W. Borst Sept 11, 1946
FINISHED BY D.W. Borst Sept 11, 1946

INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.

H1100

REVISED: I Feb. 25, 1947

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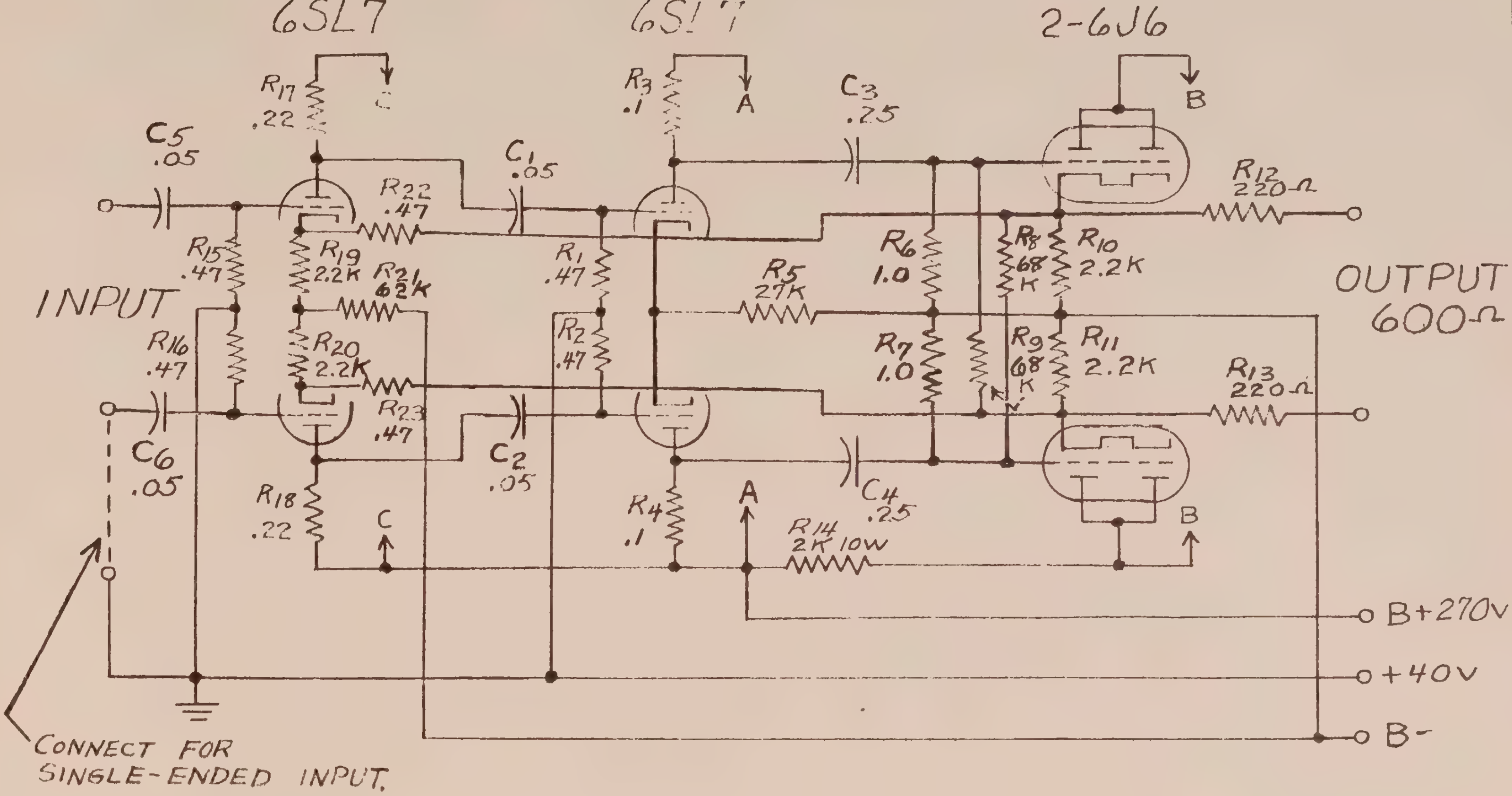

NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROFARADS UNLESS SHOWN OTHERWISE.
2) FOR INPUT GAIN CONTROL H1120 FIG. A MAY BE USED.
3) FOR POWER SUPPLY H1100 MAY BE USED.

PERFORMANCE DATA

OUTPUT LEVEL	+14 dbm
HARMONIC DISTORTION	0.5% R.M.S.
VOLTAGE GAIN	30 db
PLATE CURRENT	43 ma. (at 300v. d-c)
HEATER CURRENT	1.5A (at 6.3v a-c)

TITLE BOOSTER AMPLIFIER

FILE REF. T15.25

BEGUN BY D W Borst May 22, 1946
FINISHED BY RETRACED D W Borst Nov 2, 1947

INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.

H1099

REVISED: 1 Sept 12, 1946 2 Nov 2, 1947

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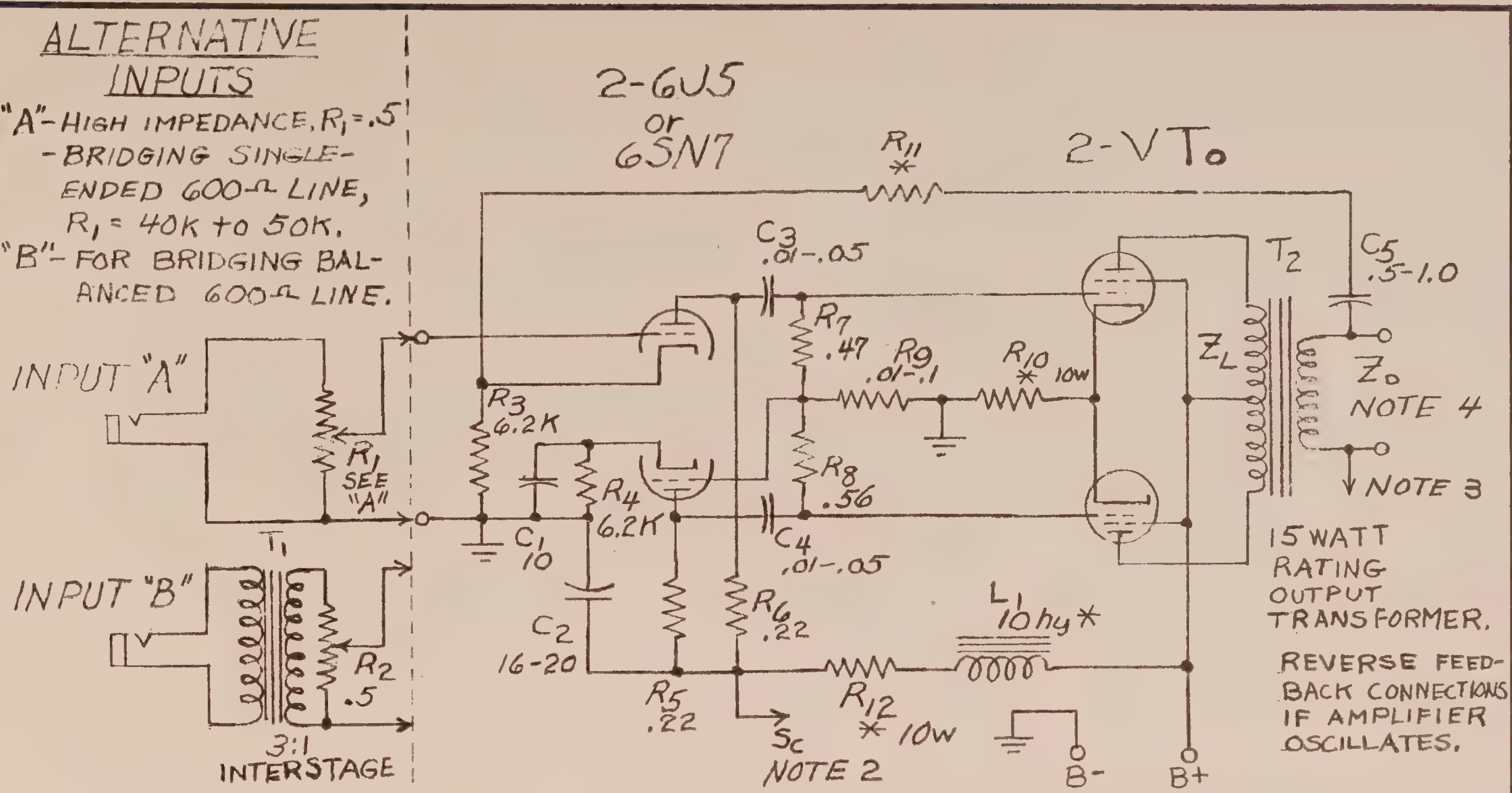


FEEDBACK DATA		
Z_o OHMS	R_{11} FOR VT_o=6F6 VT_o=6V6	R_{11} FOR VT_o=6L6
6-8	10K	16K
500-600	150K	220K
10,000	620K	910K
20,000	910K	1.3

OPERATING DATA							
VT_o	WATTS OUTPUT AND R.M.S. DIST.	B+ VOLTS	B+ CURRENT MIN-MAX	R_{10} OHMS	R_{12} OHMS (OMIT L_1)	$R_{12}+L_1$ OHMS (TOTAL)	Z_L PLATE TO PLATE OHMS
6F6	6w 3%	339	77-84	320	—	2000 NOTE 2	10,000
6V6	5w 5%	265	78-95	200	5000	—	10,000
6V6	8w 3½%	304	77-109	256	18000	—	8000
6L6	10w 2%	288	148-165	125	13000	—	5000

NOTES:

1) VALUES ARE GIVEN IN MEGOHMS OR MICROFARADS UNLESS SHOWN OTHERWISE.
2) TIE 6F6 SCREEN GRIDS TO POINT Sc.
3) GROUND DIRECTLY, OR THROUGH A 0.5 TO 1.0 MFD. CAPACITOR.
4) VALUE OF Z_o DEPENDS ON USE TO WHICH AMPLIFIER PUT. MAY BE USED TO FEED LOUDSPEAKER, LINE, OR AS A MODULATOR.
5) 6.3V A-C REQUIRED FOR HEATERS: 2.0A WITH 6F6'S, 1.5A WITH 6V6'S, 2.4A WITH 6L6'S.
6) POWER OUTPUT REDUCED FROM VALUES PUBLISHED FOR THESE TUBES TO ACCOUNT FOR LOSSES IN T_2 AND EFFECT OF POWER SUPPLY REGULATION. DISTORTION SHOWN IS RATED DISTORTION AT RATED POWER OUTPUT.

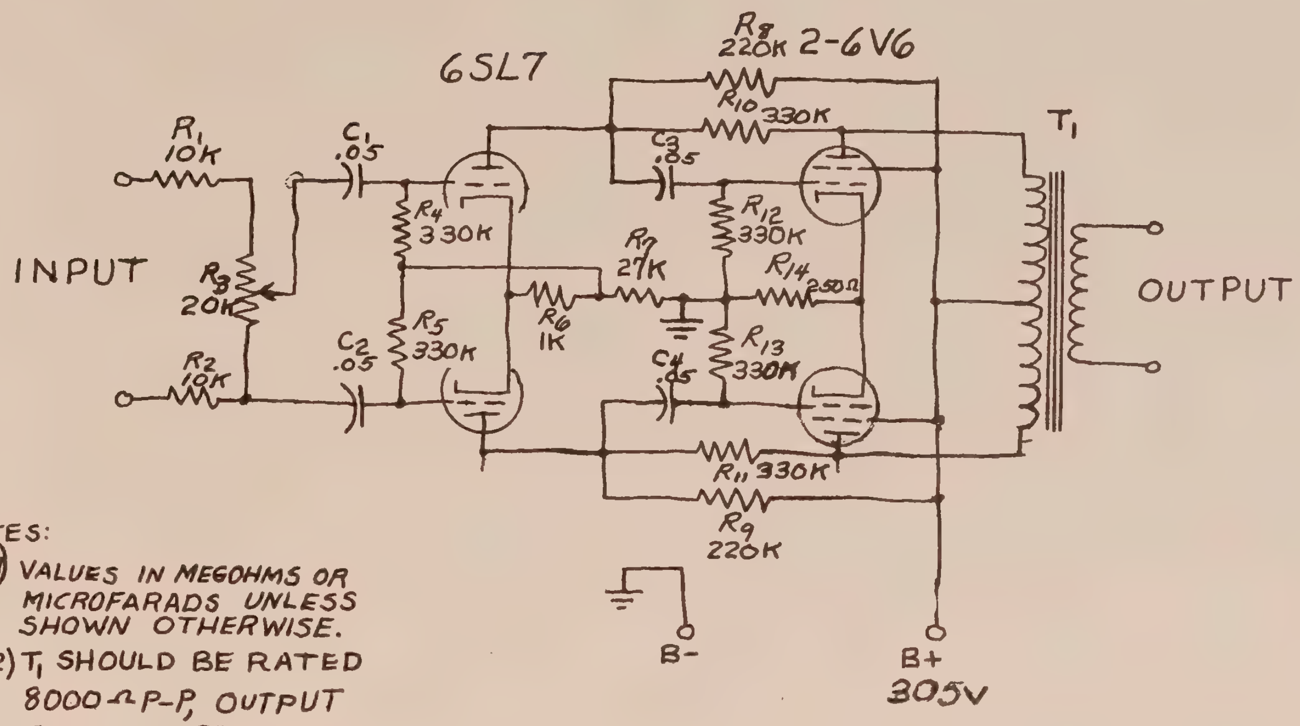
* FOR RATINGS OF THESE COMPONENTS REFER TO TABLES.

TITLE AUDIO POWER AMPLIFIER DATA

FILE REF. T15.26

BEGUN BY DW Borst Sept 29, 1944			INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1038	RK DL R PRINTS TO
FINISHED BY RETRACED DW Borst Nov 5, 1947					
REVISED: 1 Oct 27, 1944	2 Jan 24, 1945	3 Nov 5, 1947			

T152 7-7-45



NOTES:

#1) VALUES IN MEGOHMS OR MICROFARADS UNLESS SHOWN OTHERWISE.

#2) T_1 SHOULD BE RATED 8000Ω P-P, OUTPUT TO SUIT APPLICATION, 25 WATTS OR MORE.

#3) R_4, R_5, R_{13} & R_{13} MAY BE 470K.

PERFORMANCE DATA

OUTPUT LEVEL	8 WATTS
HARMONIC DISTORTION	2% R.M.S.
INPUT LEVEL	+ 8 VU (BRIDGING)
PLATE CURRENT	75 ma. (at 305 d-c)
HEATER CURRENT	1.2 A (at 6.3 V a-c)

TITLE POWER AMPLIFIER

FILE REF: T16.26

BEGUN BY D.W. Borst Sept 22, 1946	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1102
FINISHED BY D.W. Borst Sept 22, 1946		
REVISED: I June 11, 1947		

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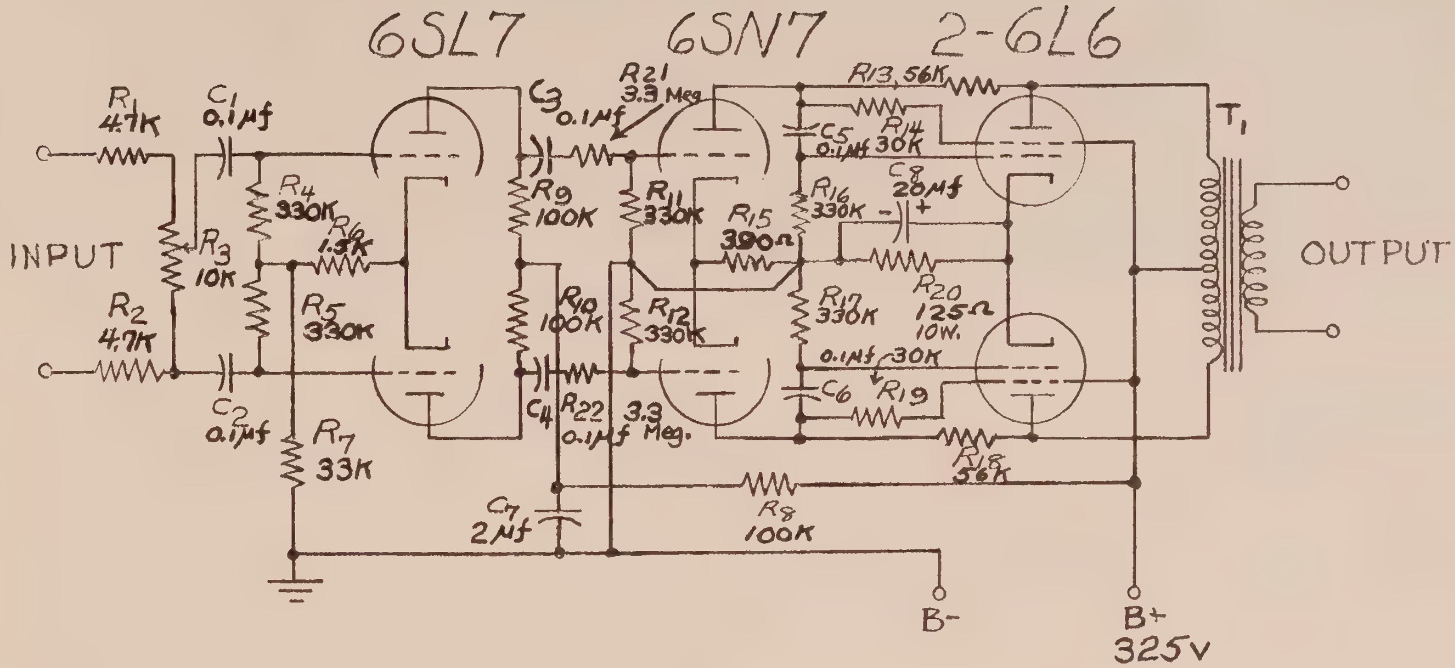

PERFORMANCE DATA

OUTPUT LEVEL	12 WATTS	15 WATTS
HARMONIC DISTORTION	2% RMS	2.5% RMS
INPUT LEVEL	+8 VU (BRIDGING)	
PLATE CURRENT	185 ma. (at 325V)	
HEATER CURRENT	2.7 A (at 6.3 V)	

NOTES:

#1) T_1 SHOULD BE RATED 4700-Ω P-P, OUTPUT TO SUIT APPLICATION, 35 WATTS OR MORE.

#2) R_4, R_5, R_{11}, R_{12}, R_{16} AND R_{17} MAY BE 470K.

#3) SIMILAR TO PAN AMERICAN ELECTRIC Co. PAB-1500.

TITLE POWER AMPLIFIER

BEGUN BY DWBorst Oct 6, 1946	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1105	GH / PY / DL / R
FINISHED BY DWBorst Jan 5, 1946			PRINTS TO
REVISED: ① May 12, 1947			

REMOTE AMPLIFIERS

A remote amplifier is a small speech input mixer and amplifier used to originate remote or "nemo" broadcasts from points where permanently installed speech input equipment is not available. Important features of their design are:

Light weight and small size for portability.
Low power consumption, and versatility with regard to power supply.
Simplicity and ease of operation.

These objectives are achieved by using as few possible tubes, and by arranging the circuit for either a-c or battery operation. One commercially available type has self-contained batteries which cut in automatically whenever the power switch is on and a-c is not available. Thus an a-c power failure does not result in failure of the program. Other makes are arranged with the batteries in a separate battery box, which is connected to the remote amplifier when battery power is required.

Since a sound insulated control booth is seldom available for remote pick up broadcasts, program monitoring is done over head phones and the remote amplifier does not include a monitor amplifier.

The program is usually fed back to the studio over an audio line, either a rented telephone circuit or a circuit erected by the station staff for the purpose, so output of the remote amplifier should be standard plus 8 VU level into a 600 ohm line.

Usually four microphone inputs are provided, and in addition there should be a master gain control. Input off-on keys for each microphone channel are usually omitted, and also there is usually no output key unless a key to select one of two audio lines is provided. This last feature is not a basic requirement. A VU meter with pad is mandatory. A variable VU meter pad is often provided, and positions on the pad selector switch can be arranged so that the VU meter can be used to check plate and filament voltages. The 100 per cent mark on the VU meter then indicates the minimum permissible voltages.

Since power consumption must be kept low it is common practice to employ a low level mixer consisting of low impedance T pad attenuators properly matched to a single microphone input transformer. This arrangement means only one microphone preamplifier tube is needed ahead of the master gain control and line driving amplifier. A transformer coupled line driving amplifier is recommended instead of the push-pull cathode follower type because power requirements will be less. Amplifier [illegible] would be suitable for the stages following the microphone preamplifier stage and master gain control.

Although it is important to keep battery drain low, the use of low voltage filament type tubes is not recommended because of their tendency to be microphonic. Thus, the 6J7 is still a good choice for the microphone preamplifier stage. Miniature tubes such as the 9001 and 6AK6 are also suitable.

If two audio circuits to the studio are available, one can be used for communications by the control operators during the program. In this case the remote operator talks over a battery-powered telephone headset. The second line can serve as a spare line in case of trouble on the line originally selected to carry the program. If only one line is available, communications between control operators can be carried on before the program using one of the program input microphones connected to the remote amplifier. Two headphone jacks across the program line should be available; one for the control operator's headphones, the other to permit bridging a power amplifier across the line in case it is possible to monitor the program this way at the remote point, or to provide sound reinforcement for an audience.

A block diagram of a remote amplifier is shown H1124. It can be seen that circuits to accomplish the functions indicated should not be hard to design. The electronic type mixer can be used but more tubes will be required. In many cases the requirement of battery operation can be overlooked, and so the larger tube complement can be tolerated. For broadcasts from locations where battery power must be used a single channel remote amplifier can be built having a minimum of tubes.

Representative commercial remote amplifiers are the Collins 12Z four channel 212F single channel remote amplifier, the RCA OP-7 four channel mixer and OP-6 amplifier, and the Western Electric 22-D four channel remote amplifier.

It is sometimes proposed to use remote amplifiers in studio control rooms in place of speech input equipment designed for this purpose. This idea has merit, but it should be remembered that the remote amplifier has the following limitations when used in this way:

1) No key switches in the microphone channels.
2) No talk-back microphone.
3) No rehearse-program key.
4) No monitor amplifier.

It is possible to wire up other amplifiers and switches to accomplish these missing functions, and this should be done if the remote amplifier is to be used this way for very long. The microphone keys are particularly important as they permit presetting the levels of the different studio microphones and interlocking these microphones with the studio monitor speaker.

References:

Broadcast Equipment, Part IV, Radio-Craft for December 1944 Page 147.

Remote Control Broadcasting, Radio News, Radio-Electronic Eng. Dept. Feb. 1946 page 14.

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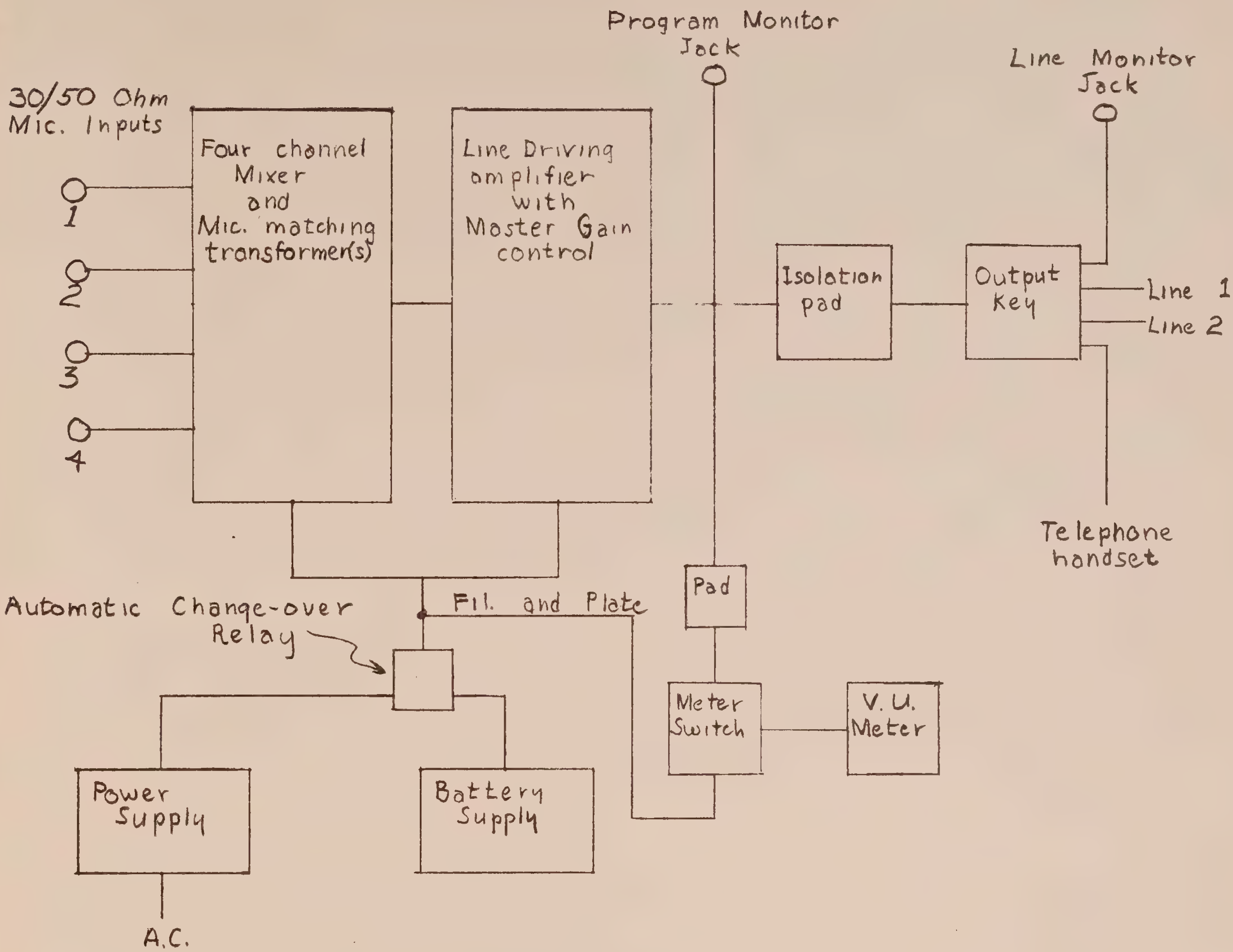


Note: Facilities for more than one output line, telephone handset, filament and plate metering, relay and battery supply are optional items.

TITLE **Remote Amplifier - Block Diagram**

BEGUN BY E R Schiffmacher - June 17-'47	INTERCOLLEGIATE BROADCASTING	H1124	PY	
FINISHED BY E R Schiffmacher - Aug 6 - 47	SYSTEM TECHNICAL DEPT.		DL	R
REVISED:			PRINTS TO	

T152 7-7-45

Engineering Note
Number 6

March 7, 1947

DESIGN OF LINEAR MIXERS

There are in general three types of solution to the problem of linear mixing. These are known as the electronic mixer, the resistance mixer, and the constant impedance mixer.

Before discussing these, it is well to define the linear mixer problem. Primarily, we are interested in a device which will add two or more signals together, giving a single output signal whose instantaneous amplitude is proportionate to the algebraic sum, or even both the positive and negative algebraic sum (push-pull operation), of the instantaneous amplitudes of the input signals.

In practice, two or more considerations enter; the frequency range over which such a mixer is to operate, and the amount of interaction between the input signals to be allowed. Usually the former is defined by the application, while the latter is usually that such interaction is to be a minimum and the two input signals are to be separately controllable (as to amplitude).

Electronic Mixers

The electronic mixer is based upon the concept of several grids controlling the same plate current or a part of it. This could be achieved within a single tube by proper construction; such tubes, having two grids, each controlling about one half the plate current through the tube (i.e. by controlling space charge around one half of the cathode) do exist. An example is the 6AS7. However, such tubes are limited in their use, particularly as the number of inputs is increased. A more practical expedient is the use of ordinary tubes in multiple, tying together their plates and/or their cathodes, and feeding the grids separately. Any ordinary amplifier circuit may be applied.

In the case of the triode resistance coupled (or transformer coupled) amplifier, two points are immediately evident.

First, since the signals are being taken off the common plate load, it makes little or no difference whether the cathodes are tied together. Second, this circuit is [illegible] the [illegible] [illegible] [illegible] of the other tube. Hence, if the mixer be symmetrical ([illegible] same tubes) which, after all, is the most practical arrangement then each tube works into a load less than its own r_p. This is a very unfortunate condition which severely limits the signal amplitude which the tube can handle without appreciable distortion. This condition becomes progressively worse as the number of [illegible], and hence tubes, is increased. This problem is solved by the addition of isolation resistors (R_I):

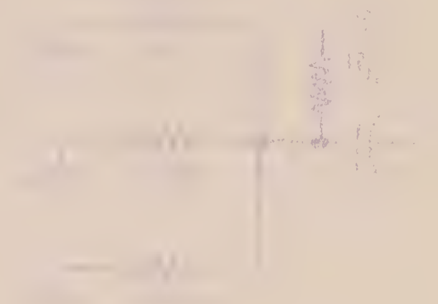


Fig. [illegible]

This sort of plate circuit has two drawbacks. First, obviously the amplification of the stage is reduced by the divider action (although increased by the increased plate loads on the individual tubes). [illegible] like this (a-c case):

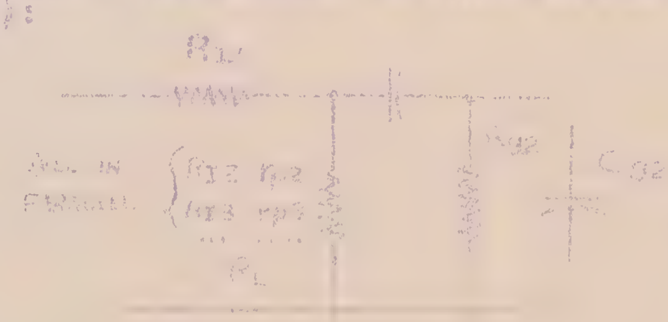


Fig. [illegible]

In short, the impedance across the points where the signal output is taken is highly (or may so be) capacitative, whereas R_I is a [illegible] R_I with a suitably small capacitor, but this would be at the expense of distortion in the high frequencies.

Altogether, the triode resistance coupled electronic mixer is seen to be none too satisfactory, particularly as the number of [illegible] is increased.

The analogous circuit using resistance coupled pentodes [illegible] [illegible] [illegible] since the plate load normally used with pentodes [illegible] less than r_p. Moreover, pentode mixers have a much higher [illegible]

[illegible]

C_{g2} will be lower than for a triode since Miller effect is absent.

The cathode follower mixer may be used, although it is subject to distortion at higher levels as the number of inputs is increased. For n tubes connected as follows:

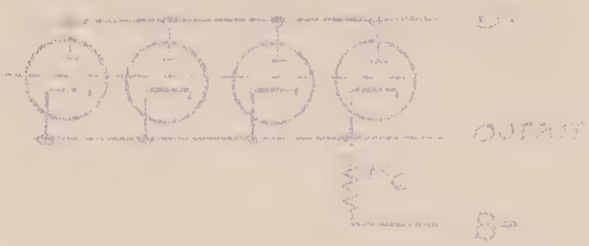


Fig. IV

the gain is approximately 1/n and the output impedance is $1/ng_m$ when all the tubes are identical. Such a mixer can be made to have extraordinarily good frequency response. A four channel cathode follower mixer was built on breadboard and had a measured response flat to [illegible] kc., down 3 db. at over 700 kc., and flat to below 50 cycles.

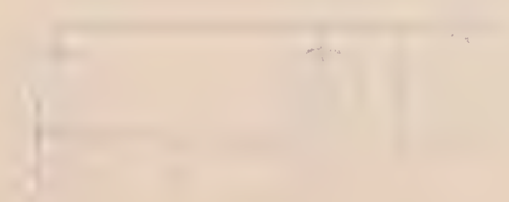
A final type of electronic mixer applicable to two inputs only is the cathode-coupled or long-tailed pair amplifier:

Fig. V

The output is push-pull for two single-ended signals; the peak-to-peak output voltage gain is:

$$\frac{\mu R_L}{r_p + R_c + R_L} \qquad (1)$$

This type of mixer may be extended to larger even numbers of inputs by adapting it into the ordinary common plate load type of electronic mixer;



This circuit is subject to all the disadvantages of the common [illegible] mixer as previously mentioned.

Resistance Mixers

The resistance mixer, as its name implies, is a resistance network so arranged that it will mix a group of input signals with a [illegible]. It is fundamentally a high impedance device and cannot be considered apart from the tube into which it feeds:

Fig. VII

The fundamental idea is that of the high impedance "leak" resistor which acts to transmit a voltage (effectively) but not a current.

For R_1 = 50K and R_2 = 500K it is seen that a signal going into one potentiometer is attenuated by the potentiometer ratio and then again by a ratio x, where

$$.333 < x < .355 \text{ (due to position of potentiometers)} \qquad (2)$$

By increasing R_2/R_1, variations in x may be arbitrarily decreased; of course, x will never be invariant, but its range can be made as small as one pleases.

The chief defects of the resistance mixer are three:

1.) Level of the various inputs is not completely independent.
2.) It is a high impedance device.
3.) The frequency response is limited by the value of R_2 and the input capacity of the following tube. (It is best to use a pentode.)

However, if we can allow some variation in x, we may get a very fine frequency response from such a system.

Constant Impedance Mixers

The constant impedance or pad mixer is a mixer based upon the constant impedance properties of resistance attenuators (pads). Such mixing may also be accomplished with suitable reactances, but

resistance pads are most common.) Fundamentally, there are two types of such mixers; series and parallel. Such networks are usually low impedance, and little or no frequency discrimination is encountered. The chief disadvantage to such circuits is that they use up a considerable amount of power.

The configurations of such circuits vary according to the number of inputs. Some examples follow:

2-Channel
Series:

Fig. VIII

T pads are shown- analagous circuits may be built up of ladder pads.

This circuit relys on the action of the matching transformer which follows for the mixing action, hence will give push-pull output. If input circuits are push-pull, H pads are used.

2-Channel
Parallel:

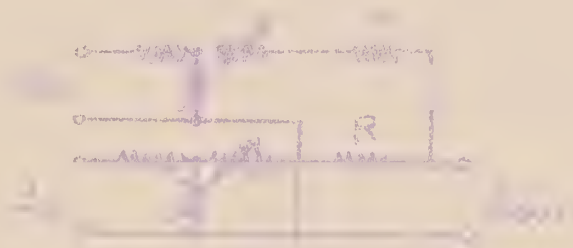


Fig. IX

Single ended inputs and output.

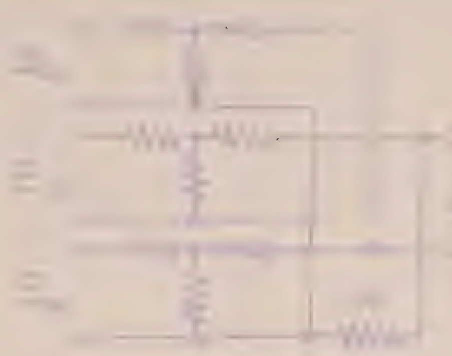
Circuit may be extended to n inputs:

$$R = \frac{Z_{in}(n-1)}{n} \tag{3}$$

$$Z = \frac{Z_{in}(2n-1)}{n^2} \tag{4}$$

Follow mixer with a taper pad if it is desired to feed impedance same as Z_{in}.

[illegible]
Parallel-
Series:



This circuit also relies on the action of the output transformer for mixing.

Pads may also be connected in a bridge circuit. This configuration makes a good four channel mixer.

T pads are usually used where the insertion loss (loss with pads set to zero attenuation) must be kept to a minimum, as in a low level mixer which mixes the output of several microphones prior to any amplification. Low level mixers are commonly used today only in equipment where the number of stages must be kept to a minimum, such as in remote amplifiers.

Ladder pads are usually used in high level mixers (mixers fed by microphone preamplifiers which raise the audio levels) because they are less expensive than T pads (they have fewer variable elements), but they have a greater insertion loss which makes them unattractive in low level circuits.

References:

Radiotron Designer's Handbook, Third Edition, pages 91-93
Audio Mixer Design, Electronics, June 1945, page 120
Studio Facility Expansion, Communications, April, 1945, page 41.
Catalog, The Daven Company, Newark, N.J.
Reference Data for Radio Engineers, Second Edition, published by Federal Telephone and Radio Corporation.

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Engineering Notes are issued from time to time by the Technical Department, [illegible] Schenectady 2, N.Y.

Engineering Note
Number 18

Dec. 9, 1948

Procedure for Taking Field Strength Measurements

Note: The following is the recommended procedure for making Field Strength Surveys on college campuses. All persons making surveys should follow the procedure below in order to obtain uniform and acceptable results.

Introduction

The Federal Communications Commission requires that all measurements of radio frequency field strength for frequencies below 18 mc. be made with a loop antenna. Thus basically this rules out the use of any instrument having a whip or straight wire antenna. Furthermore, in the interest of accuracy, some standard of strength must be used so that the measured signal may at all readings be compared with a know signal. Two general methods of doing this are now accepted. The first is the substitution method where the loop of the field strength meter is oriented to maximum and the reading of a microammeter in the second detector circuit is read. The loop is then rotated until minimum signal is received and a voltage is introduced in series with the loop from a signal generator tuned to the same frequency, and the output of the signal generator is then varied until the same microammeter reading is observed. The output of the signal generator is at this point equal to the induced voltage acting in series with the loop.

The second method of calibration involves adjusting an I.F. attenuator to give a convenient deflection of a microammeter in the second detector circuit. An auxiliary oscillator is then tuned to the frequency of the signal and adjusted to give a standard voltage, usually 1 volt, in series with the loop antenna and the I.F. attenuator is readjusted to give the same reading as that previously observed. The signal voltage at the grid of the converter tube during measurement is then x-y below 1 volt, where x and y are the two attenuator settings, in db. This voltage differs from the voltage actually induced in the loop antenna by the amount of resonant rise of voltage in the loop, and by the amount of gain or loss in the circuits between the loop and the converter stage. The ratio of these last two voltages is then determined by removing thr comparison oscillator from the loop and applying it to the converter without changing the oscillator output used to get y. The I.F. attenuator is then adjusted to the value "z" required to give the same microammeter deflection as before. The voltage actually induced in the loop is then 2y-x-z db. below 1 volt.

Commercial instruments like the Federal or R.C.A. models make use of either of the methods, or some modification of them, and thus are acceptable standards of measurement. Any home built instrument which does the same thing is acceptable, but the usual amateur method of measuring the a.v.c. even with a meter calibrated against known standards does not give true readings because

1) Variations in tube constants are not taken into account after the original calibration has been made.
2) Low signals cannot be read with sufficient accuracy, since r.f. attenuators that will maintain calibration are very difficult to incorporate into circuit design.

The procedure to follow is given on the back of this page.

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Engineering Director

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Intercollegiate Broadcasting System, WKRC Hamilton Annex, Columbia U., N.Y. 27, N.Y.

Procedure

I. Record Transmitter final r.f. stage plate current and plate voltage. Record r.f. current into r.f. line(s) and r.f. voltage across line(s). (If more than one transmitter, record above for all transmitter as survey proceeds. If you have any linear r.f. amplifiers, to boost r.f. on the line at some point, record plate and line currents and voltages as above. Note whether r.f. amplifier is operating Class A or Class B).

II. On a large scale map of the campus area, (indicate approximate scale if unable to procure a scale map) record the following data noting the direction in which the maximum signal is observed at each point where a reading is taken:

In daytime:-

1. In each dormitory measure campus station signal strength. (It is a good idea to take readings on several floors, and indicate the maximum and minimum readings obtained in each dorm.)
2. At a central point among the dormitories measure the field strength of each local station.
3. Measure field strength of campus station at at least 2 or 3 points along each major line of the r.f. transmission system. Make from two to five readings at each point by moving away from the line until the signal level drops to 15 microvolts per meter, or begins to increase due to proximity of other r.f. lines, etc.
4. Measure field strength of campus station at at least 2 or 3 points along all secondary (115/230 v. circuits) lines that are coupled into and which therefore carry your r.f. Take from 2 to 5 readings the same as in step 3. Note distances if map is not to scale.
5. At at least 4 points outside of campus area, and be sure to go in each major direction away from the campus, measure the signal of your campus station where it can be picked up. Indicate also the location of all high voltage feeders which radiate your signal as they approach or leave the campus. Take readings to indicate the amount of radiation from these feeders the same as you previously did when checking your own r.f. lines in step 3.

Note

During these tests make sure that you actually have your own station and not an interfering station on the same frequency. If the strength of other stations on your frequency is appreciable, move your station to a nearby channel which is free of such interference for the tests, (or permanently if justified!). If it is not possible to find a channel where other stations during the day are weak enough, then you will have to make your measurements when no other station is on the air. This may only occur very late at night, between 1 or 2 AM and 6 or 7 AM.

At Night:-

1. During these testing nocturnal period repeat some of the readings taken in 1,2,3 and 4 for comparison. You will probably not be able to repeat your readings down around 15 microvolts per meter because of the greater signals put in by other stations on your channel due to the night-time sky-wave effect.

III. Note noise level and level of other stations on your station frequency at various times of day and evening up to midnight (your station will of course be off the air for this test).

IV. Mark in colored pencil on the campus map the line wiring on your campus, and the route of your r.f. lines.

V. Make a [illegible] diagram of your r.f. transmission system [illegible]

INSTALLATION OF R.F. TRANSMISSION LINES

Type of Wire

In all instances twisted pair wire is recommended for transmission of radio frequency power in preference to 300 ohms or 70 ohms parallel flat wire or coaxial line. Parallel flat wire may not have a high enough tensile strength for all outdoor installations, and the plastic insulation may soften in warm locations such as heating tunnels. In addition, a very powerful argument against parallel flat wire is that it is designed for transmission systems which are properly matched so that standing waves are essentially eliminated. It is practically impossible to maintain a matched line in carrier current service, as is explained in section TI-3151, and so radiation from parallel flat lines might be greater than with twisted pair, where the conductors are more closely spaced. Thus, the extra cost of parallel flat wire is not justified.

There are some apparently good reasons for using coaxial line, but they should be considered carefully. It is argued that today coaxial cable can be purchased at low cost as government surplus. Consider the fact that in future years cable purchased today must be replaced, or the r.f. system may have to grow. Coaxial cable may be expensive then. It is difficult to use both twisted pair and coaxial cable in a given r.f. system; the two cannot be spliced directly together. The twisted pair lends itself to a balanced r.f. transmission system, which helps reduce radiation; however, the coaxial line is unbalanced since the outside must be grounded. A coupling circuit is required when going from one type of line to the other, and coupling circuits at the ends of the two types of line have to be different. These considerations indicate the desirability of selecting twisted pair wire for r.f. lines.

In a few instances shielded twisted pair wire has been used for r.f. lines, the shielding being used in an effort to reduce radiation. The expense of using shielded wire can usually be avoided by feeding the transmitter's power out over a number of lines instead of trying to use a single line to do the whole job. The better shielding of coaxial and shielded twisted pair lines is generally not needed as it is not difficult to operate twisted pair lines in a manner that will insure negligable radiation from the lines.

If the r.f. lines are to be strung overhead wire of adequate tensile strength must be selected. In addition to the weight of the wire itself, the force of the wind and icing must be considered since their total effect can produce considerable stress. For normal installation AWG #19 or larger conductors should be selected. A hard-drawn single conductor is to be preferred to a stranded conductor. If a span over fifty feet long is contemplated, calculations should be made to make sure that the wire will withstand the elements.

If the r.f. lines are to be installed in heating tunnels, moisture and heat may be encountered which will render the selection of a suitable wire more difficult. In this case a wire having insulation which will withstand the service conditions must be found. Plastic insulated wire (vinylite and similar plastics) will withstand high humidity but this insulation may soften in the presence of excess heat. Outdoor service telephone wire having an asphalt impregnated insulation usually works well at high temperatures; at least as high as those found in heating tunnels in general.

Sometimes it is necessary to bury the r.f. line in a trench, there being no other way. BX cable having two conductors which are insulated and then sheathed in lead can be used for this service; it is often referred to as BXL. Other suggested cables for this purpose are lead covered cable without the BX armour, and parkway lighting cable which is intended for burying.

The choice of the twisted pair wire to use is seen to depend upon two factors: adequate tensile strength, most important for overhead lines, and adequate insulation [illegible]

11/30/47

Tabulated below are some of the commercial transmission lines which may be suitable, together with comparative list prices as of 1944:

Description	1944 Price
Twisted outdoor service telephone wire (copperweld) #17 AWG	$33.50 per 1000 ft.
Alpha 1155- E01 transmission cable, #12	47.50 (500 ft. spool)
Alpha 1157-Transmission line, 72 ohm #12	29.25 (four 100 ft. spools)
Belden 8210-E01 transmission cable, #12	(500 ft. spool)
Belden 8204-Transmission line, 72 ohm,#18	(500 ft. spool)
Birnbach 914-Transmission line, 72 ohm,#16	39.00 (500 ft. spool)
Birnbach 919-Commercial twisted pair, #18	23.00 (500 ft. spool)
Birnbach 909-Transmission line, 72 ohm, #14	45.00 (500 ft. spool)
Birnbach 958-Transmission line, 100 ohm, #12	52.50 (500 ft. spool)
Birnbach 954-E01 transmission cable, #12	75.00 (500 ft. spool)

Note:
Not recommended are Alpha 1146, 1269; Birnbach 952 and Belden 8205.

Installation of Lines

The fact that there is radio frequency energy in the twisted pair lines must not be forgotten when installing them. At audio frequencies the insulation on the wire may be sufficient to insulate the conductors from supporting structures, but at radio frequencies the wire must be supported by an insulator of high dielectric constant. Such a material is found in glass, steatite or porcelain.

Sometimes to satisfy the insulation requirements the common nail-it knob has been chosen. This insulator was designed for inside installations with heavy wire having equally heavy insulation, and it <u>should not</u> be used for radio frequency lines. There is a much better type of insulator available which does not squeeze the wire (causing it to break) and which also eliminates the possibility that the fastening nail might cause an accidental r.f. ground.

These preferred insulator knobs are installed as shown in Fig. 1 of H1075. The knobs are available with one to five grooves, thus making it possible to mount several lines from the same support. A 12 inch length of heavy wire is required to hang the transmission line; this is far superior to wrapping the r.f. line itself around the knob. A fastener for the knob completes the assembly.

A more expensive insulator which is used in much the same manner is provided with a threaded stud for screwing into convenient wood objects like buildings, trees, etc.

Whenever a sharp bend must be made the suprort should be spread over a length of wire and the right-angle configuration avoided. This can most easily be done by using a strain type insulator and a length of heavy wire approximately 24 inches long as shown in Fig. 2, drawing H1075. A similar procedure is followed when attaching the line to a building and bringing it inside, as shown in Fig. 3 of drawing H1075. The porcelain tube shown should slope down toward the outside to prevent moisture from entering the building at this point.

Overhead lines may be supported with insulators such as these from most convenient objects. Permission should be sought in all cases, of course; the use of power poles to support r.f. lines can often be obtained in this way. The use of trees to support lines may not be possible because the trees are insured; so be sure to find out how you stand on this point before making a lot of plans.

H1075

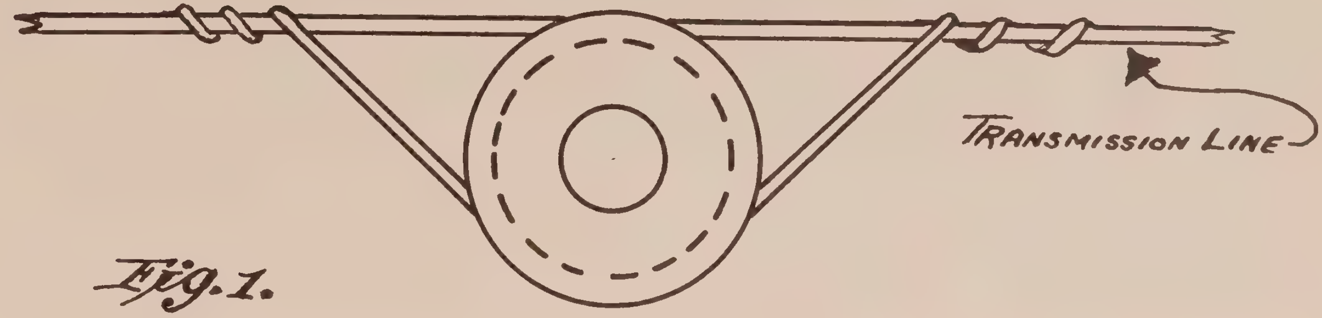

Fig. 1.

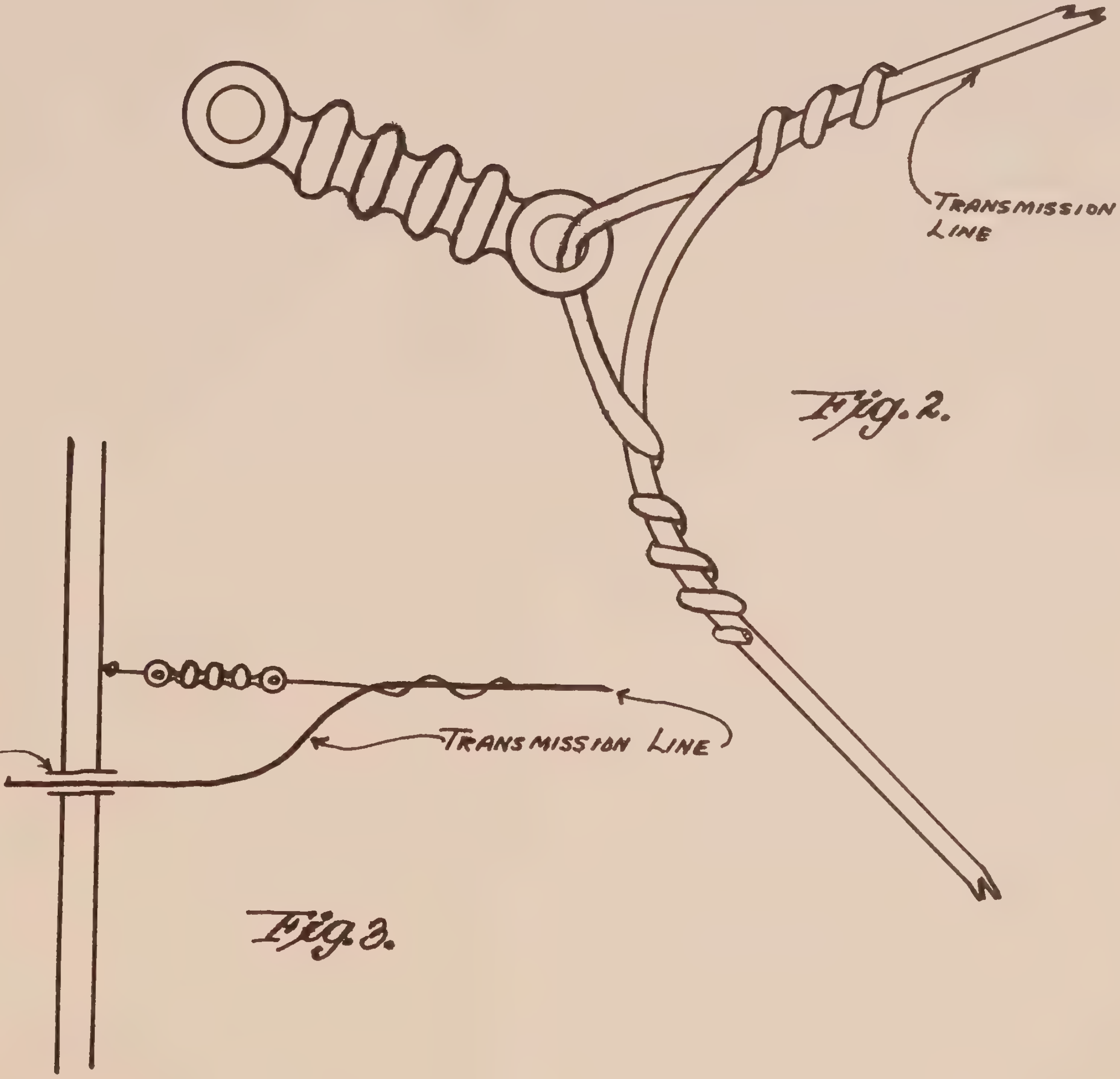

Fig. 2.

Fig. 3.

TITLE TRANSMISSION LINE INSTALLATION

FILE REF: T15.31

BEGUN BY H. B. Barlow, Jr. 8-25-47	INTERCOLLEGIATE BROADCASTING	H1075
FINISHED BY H. B. Barlow, Jr. 8-27-47	SYSTEM TECHNICAL DEPT.	
REVISED:		

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PRINTS TO

T152 7-7-45

Installation of Lines (Cont'd)

If permission is obtained to install r.f. lines on power poles they should be installed well below any of the power conductors on the same poles.

Installation of r.f. lines underground in heating tunnels results in two advantages; reduction in radiation from the line, and longer life to the line because of protection from the elements. In addition, the line is out of sight which in many cases is a requirement which must be met. The line should be supported in the tunnel in much the same way as is done for outdoor lines, except that support points can be made closer together so the wire will be subjected to less stress. Keep the line well away from any power conductors, and any unshielded telephone circuits which may be present. These circuits will usually be found installed in conduit or lead sheathed cable so no problem will exist.

R.F. Lines may also be installed underground in conduits, if these are available. Conduits may be used only if they are empty; radio frequency lines may not occupy the same conduits as power circuits. A study of the campus power wiring map may reveal the presence of spare or abandoned power conduits which can be appropriated for the purpose of running r.f. lines.

If the wiring must be run in the same ducts or other enclosures which carry power circuits, then the conductors of the power and r.f. systems must be separated by a partition. If further research on this subject is necessary, read sections 3013, 8012 and 8023 of the 1940 National Electrical Code.

Where wiring must be underground and no tunnels or conduits are available, the lines can be installed in a trench, using a lead covered wire as mentioned in the previous section. The trench should go below the frost line, to prevent movement of the cable in the spring from frost action. If splices are necessary, they can be made using an ordinary galvanized steel interior junction box, and after soldering and taping the conductors this box should be filled with asphalt potting compound.

It can be seen that some ingenuity may be required to install the r.f. wiring; especially if circuits must be run underground. The extra effort required to put the lines underground will be repaid in the long run because of the increased reliability of the circuits. In considering the various possible ways of getting r.f. where you want it, don't make the mistake of asking the telephone company if you may send r.f. over their lines. This is not permissible because some telephone equipment operates on radio frequencies (up to about 300 kc) and so your signals might possibly cause interference to this service, but in addition, the type of cables used by the telephone company are not intended for carrying r.f. The insulation is of the wrong sort, and might not withstand the voltages present when r.f. is coupled in.

[illegible]

R.F. LINE COUPLING METHODS

General

The coupling between the transmitter and the transmission lines, which may be networked throughout the campus or run directly to the primary high voltage feed for the campus represents the last element of the radio frequency equipment. Properly designed and applied, couplers will transmit up to the full power available from the transmitter. Where taps are taken from a main feeder r.f. line, an intermediate coupler will usually improve the impedance match between the line and the load, and will therefore reduce the standing wave ratio (but under practical considerations never eliminate standing waves). The reason for this is that the ultimate r.f. loads (the lighting circuits) change their impedance during the day as the power load varies. Intermediate couplers partially compensate for this since the amount of impedance mis-match that will be reflected back is dependent upon the coefficient of coupling. An alternative to using intermediate couplers is to run several r.f. transmission lines to individual coupling points from individual coupling units at the transmitter.

In general, a coupler should take the form of a tuned circuit that is link-coupled in at least one direction. Several different types of circuits are shown on the following pages which all have their peculiar advantages. Coupling starts at the transmitter where a link or links are taken from the final tank and run directly to a coupler or couplers located at the transmitter which in turn feed one or more r.f. transmission lines. In several instances a direct link feeding the transmission lines has been tried, but this is not recommended practice because there is a greater chance that the reflected impedance from the lines, which as has been noted before changes throughout the day, will cause detuning of the transmitter tank circuit.

Coupling from the Transmitter to R.F. Lines

Several suitable schemes are shown on drawing H1129 for coupling to double-conductor lines. In all cases the middle conductor (terminal) represents the ground lead which should be grounded to a good electrical ground at the transmitter location to reduce radiation from the lines and to provide a balanced feed system. In the first sketch is shown a simple series-resonant circuit that is not generally recommended, as is the case with all series-resonant circuits, since it presents a low impedance to the line at r.f. frequencies. More generally used, and strongly recommended, is the parallel-resonant type of coupler, which is shown in many forms.

In all cases the tank circuit set up by these couplers is designed to tune to the transmitter output frequency, thereby giving an isolation stage to help suppress harmonics. In all these circuits it is often convenient to use a split-stator 350 mmfd. per section capacitor for tuning. By grounding the rotor of this capacitor a very convenient center-tap grounding point is found, which eliminates the necessity for center-tapping the coil, and is, incidentally, more accurate a means than can usually be obtained by bringing out the mid-tap from a hand-wound coil. (These remarks apply, of course, only to those circuits where the coil is shown grounded at its mid-point.)

Adjusting the Parallel-Resonant Coupler

The parallel-resonant coupler with taps shown in detail on E1008, is perhaps the most universally-met coupling device; the variable tapping

[illegible]

[illegible] taps generally are not at the extreme ends of the coil, the [illegible] across the tank as a whole is usually higher than the [illegible] line. The reflected reactance is equivalent to an inductance [illegible] (depending upon whether the line is inductive or capacitive) [illegible] the circuit, consequently, is detuned, and the [illegible] adjusted to resonance. [illegible]

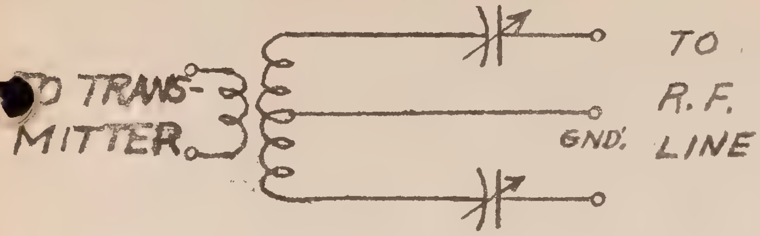
[illegible]

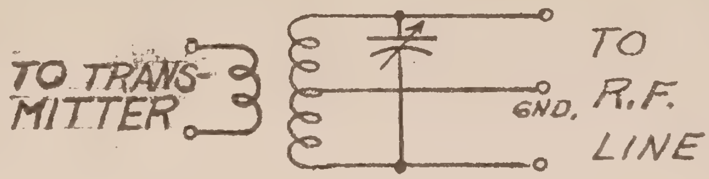
[illegible] coil must be used as a [illegible].

To tune up the system, first disconnect the transmission line [illegible] from the coil. Loosen the coupling to the final tank of the transmitter as much as possible, and tune the coupler circuit to resonance as indicated by a very slight kick in the current in the transmitter plate tank, the plate tank having been adjusted for minimum plate current, as usual. Do not use too much coupling as it will cause an appreciable reaction on the final tank. The coupling should be so loose that the final tank will not require readjustment for minimum plate current when the coupling circuit is brought to resonance. Next tap the transmission line to the coil using a small number of turns each side of center for a start. Retune the coupler circuit to determine whether more or less capacitance is required to bring the circuit to resonance. If the capacitance must be increased the transmission line is inductive and a compensating condenser must be connected across the line. If less capacitance is required, the line is capacitive and a coil must be connected across the line. Connect the appropriate element across the line and re-resonate the coupling circuit with the line disconnected from the taps. Reconnect the line to the taps and readjust the coupling circuit until the whole system is resonant as indicated by a kick in the final plate current. With the correct value of compensating capacitance or inductance it should be possible to connect or disconnect the transmission line from the taps without changing the tuning of the coupler circuit.

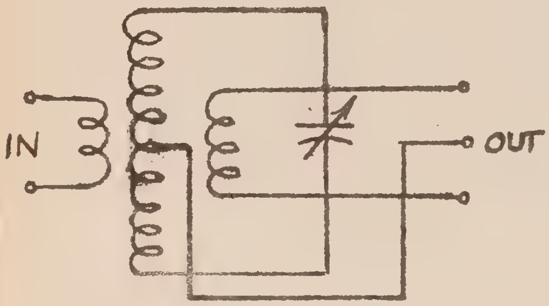
[illegible] component of the line to the [illegible] increased, there is a decrease in the [illegible] to the closer coupling to [illegible]

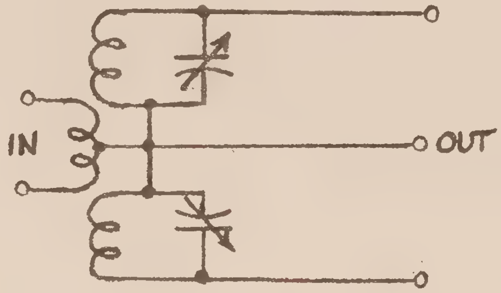
BASIC SERIES RESONANT - BASIC PARALLEL RESONANT

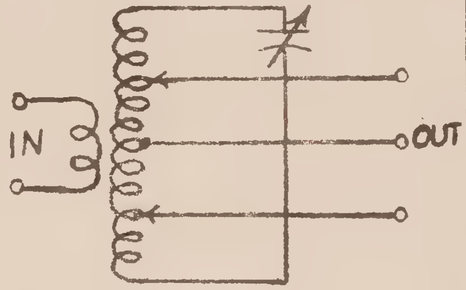




SIMPLE LINK - VARIABLE-BALANCED VOLTAGE FEED - TAPPED PARALLEL RESONANT

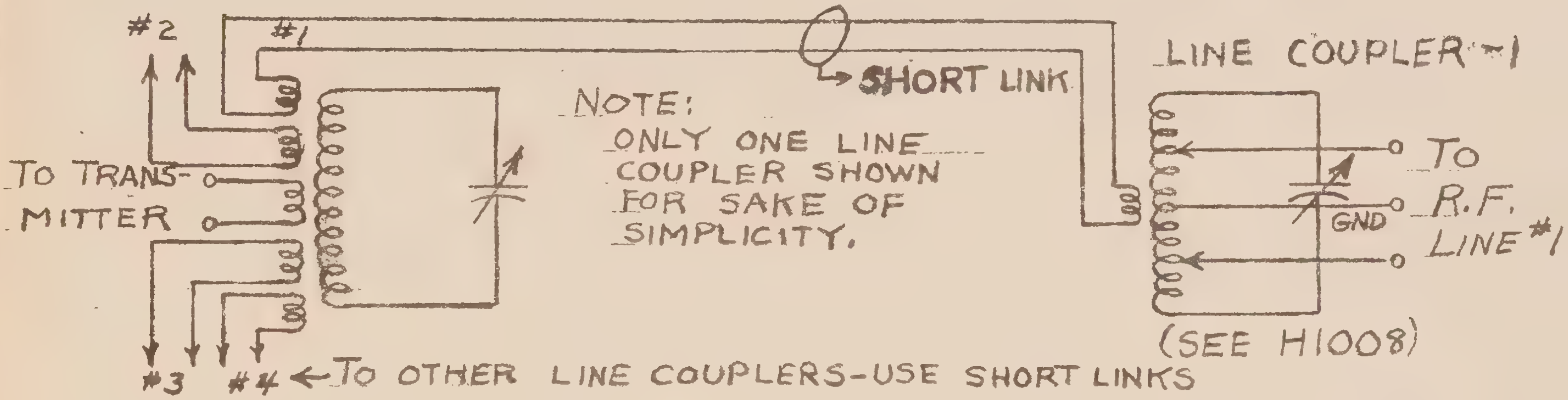




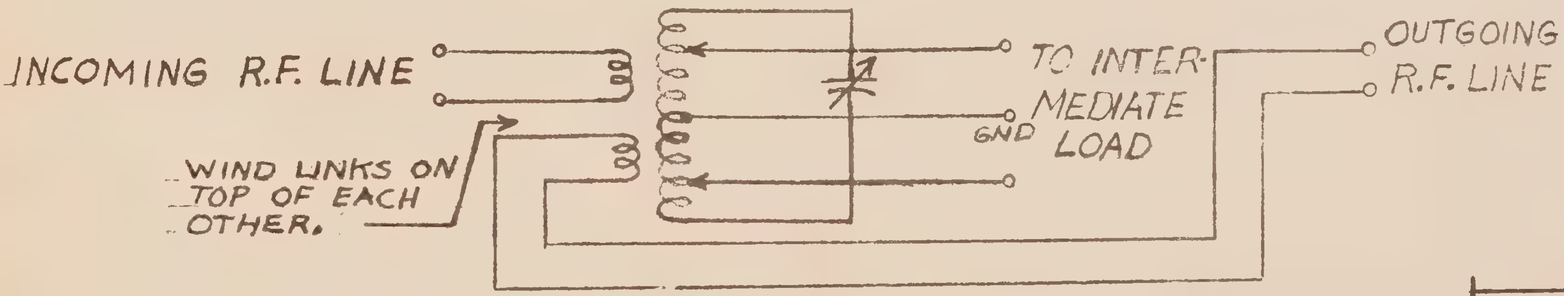


(SEE H1008)

AUXILIARY COUPLER



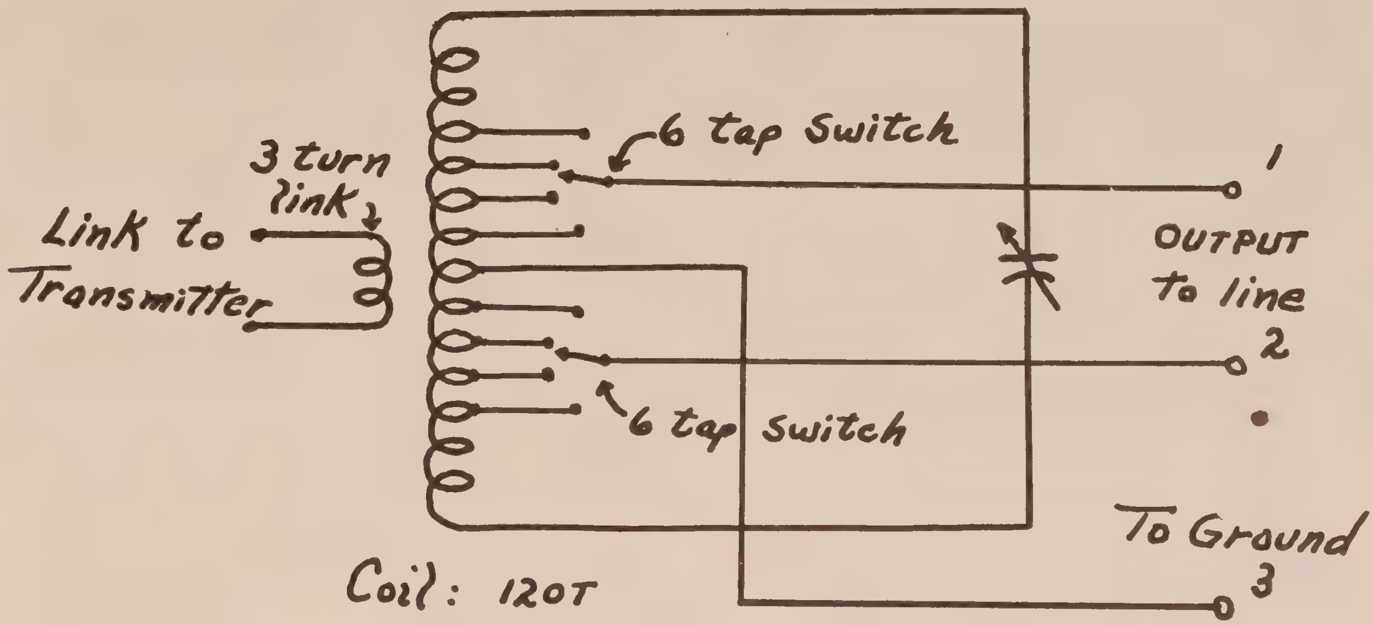
INTERMEDIATE COUPLER



TITLE	R.F. LINES COUPLING METHODS					HB
FILE REF. T15.33						PY
BEGUN BY H Barlow Aug 15, 1947	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.		H1129			DL
FINISHED BY D.W. Borst Dec 2, 1947						R
REVISED: A Dec 9, 1947	B Oct 5, 1948					PRINTS TO

T152 7-7-45

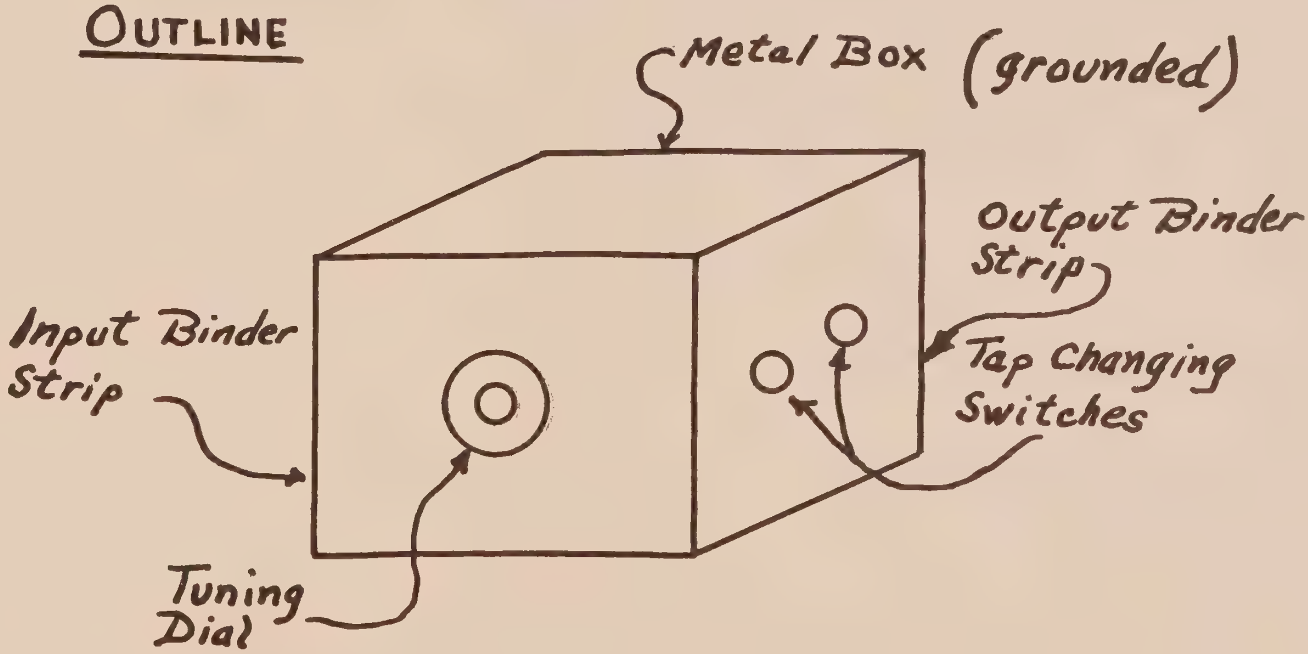
H 1008



Coil: 120T
#22 d.c.c.
2 inch form

Taps at 48, 50, 52, 54, 56, 58, 60 (mid)
62, 64, 66, 68, 70, 72 turns

OUTLINE



TITLE Coupling Device

FILE REF.: T15.33

BEGUN BY D.W. Borst Sept. 9, 1941 FINISHED BY retraced H. Barlow Sept '41	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H 1008
REVISED: (1) Jan. 24, '45		

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R
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[illegible]
loose coupling means less harmonic transfer.

The amount of L or C required to correct the line depends upon the line length, the characteristic impedance of the line, and the standing wave ratio. An approximation to this value for standing wave ratios above 10 is as follows; the minimum reactance required is nearly equal to twice the characteristic impedance of the line divided by the standing wave ratio.

It should be remembered that it is entirely possible and probable that the standing wave ratio on the lines of a carrier current system will vary depending upon the amount of load that is being taken from the lighting circuits that are being fed. Therefore, to approach a more perfect match a separate line should be run from a separate coupler for each load that is being fed, or more practically, keep the number of taps on the line down [illegible]

Auxiliary Coupler

The best way to assure low standing wave ratios on the lines of the r.f. system is to run a line from each load back to the transmitter. Where a large number of loads is involved it may be uneconomical to do this; the best procedure then is to run four or five lines from the transmitter, each line feeding a group of buildings which are close to each other.

Each r.f. line should be fed with a tapped parallel resonant coupler of the type shown on [illegible] and [illegible]. As each of these couplers is fed by a link, it then becomes necessary to devise some way of coupling these four or five links to the transmitter tank. One way to do this is to use the auxiliary coupler shown on [illegible]. Use of this coupler between the transmitter tank and line couplers will insure that each of the lines receives an equal share of the output of the transmitter.

The auxiliary coupler is link coupled to the tank of the transmitter's final stage. The tank of the auxiliary coupler is left "floating", i.e., not grounded at any point, and does not have any taps on the coil. The links feeding the line couplers are placed indiscriminately along the coil of the auxiliary coupler.

The theory behind this auxiliary coupler is that each link will cut the same lines of force around the coil and receive, therefore, equal energy from the main link that leads to the transmitter. If the links from the line couplers were all coupled to the final tank of the transmitter they [illegible] would obviously not receive the same power because of voltage distribution along the final tank coil, but with this auxiliary coupler arrangement all lines may be fed equal power, if desired; the degree of coupling being adjusted at the individual couplers that feed the lines, by varying the link coupling and/or the taps.

Intermediate Couplers

As just explained, it is best to run separate r.f. lines from numerous couplers at the transmitter to each load that is to be fed. This may not always be possible, especially when the number of loads is large. In this case it sometimes becomes necessary to tap r.f. from the line at various points along it. It is obvious that this will introduce severe impedance discontinuities along the line if direct taps on the line are taken. If all of the loads tap off near the end of the line, the mismatch to the loads can often be tolerated. However, if a tap must be [illegible] inserted in the line to insure adequate power being fed down the remainder

to the nearby load through taps on the coil. ... mission line is connected a link which is ... the incoming line feeds. It can be seen that ... intermediate load can be controlled by adjusting ... ergy not fed into the intermediate load is coupled ... through the second link. The outgoing r.f. line ... intermediate couplers like this one, or it can feed ...

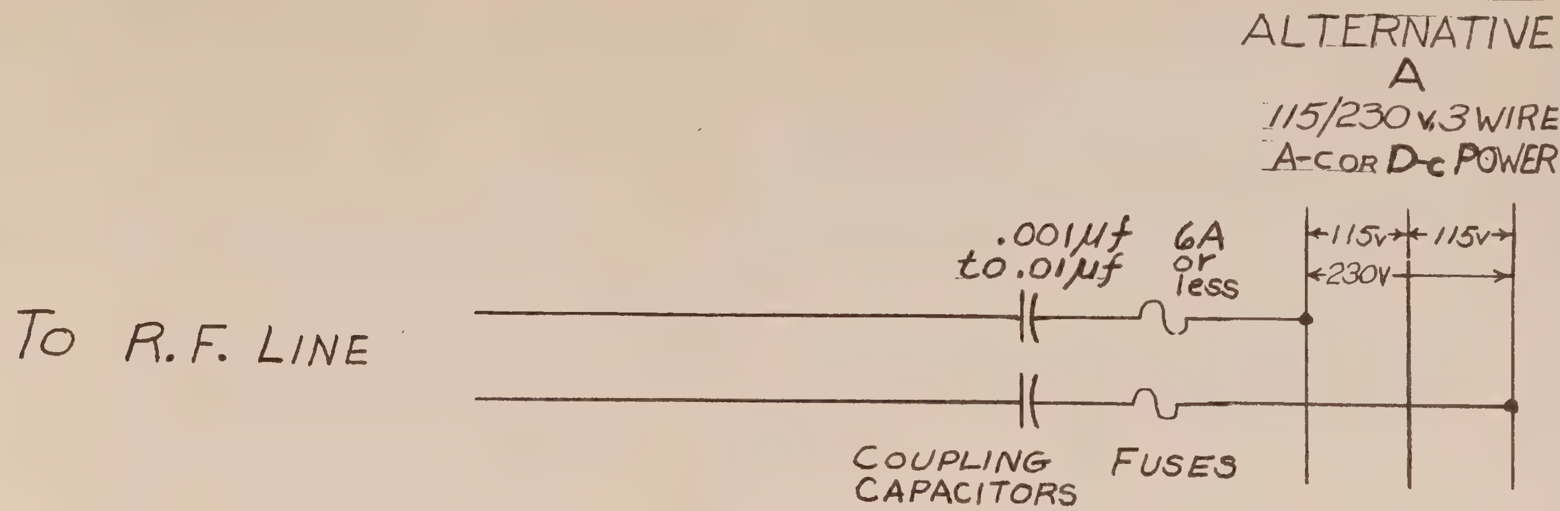

FIG. 1

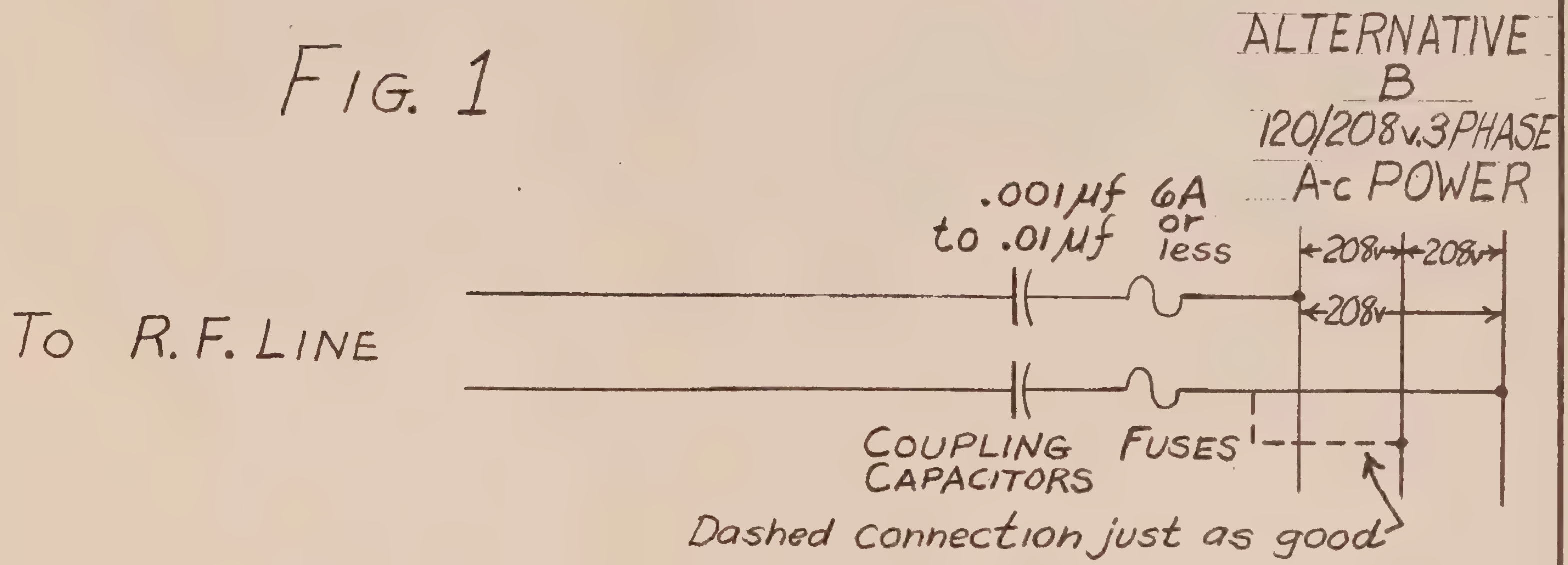

FIG. 2

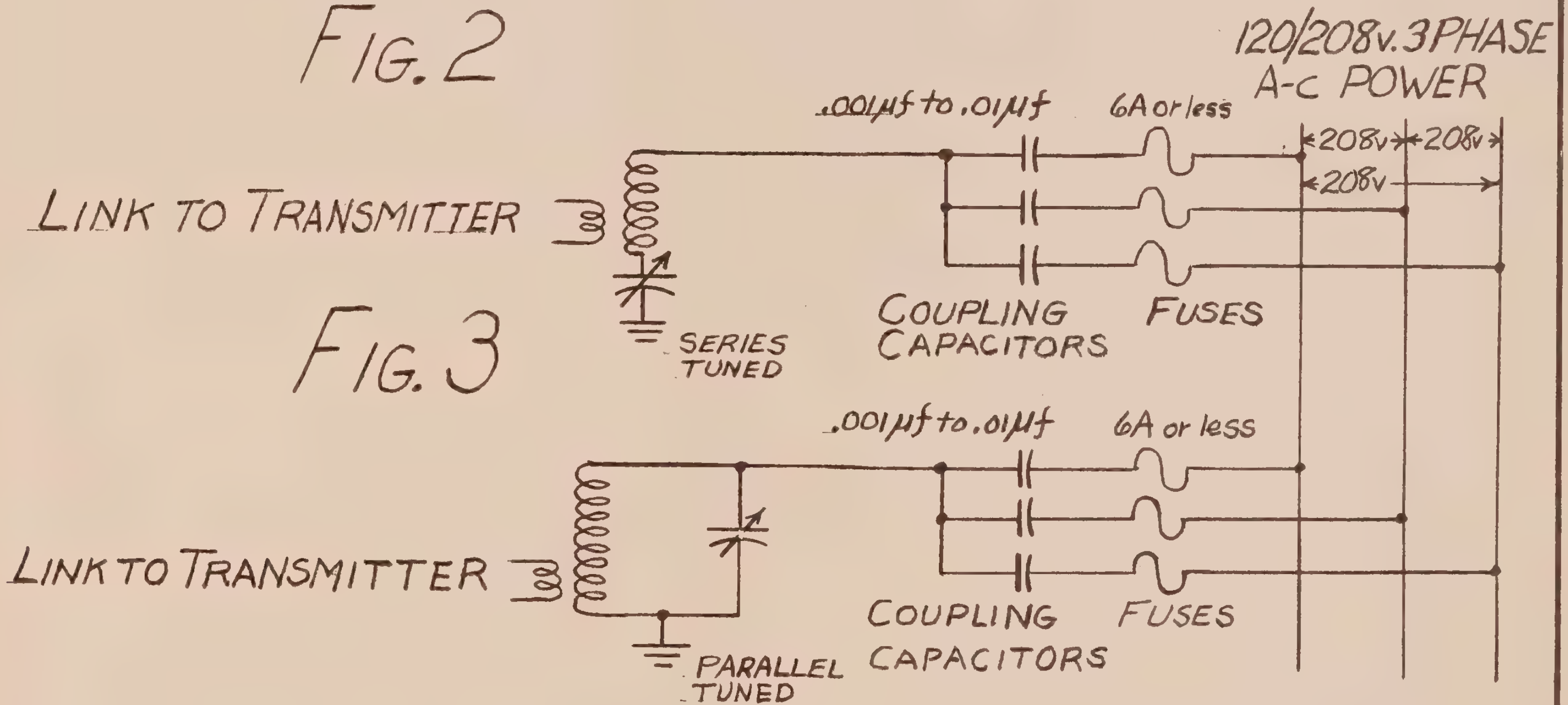

FIG. 3

TITLE R.F. COUPLING TO LOW VOLTAGE POWER CIRCUITS

FILE REF. T15.33

BEGUN BY D.W. Bont Dec 4, 1947 FINISHED BY D.W. Bont Dec 4, 1947	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1130
REVISED:		

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third, uncoupled, phase, then the circuits shown in Fig. 2 and Fig. 3 of H1130 can be tried.

Figures 2 and 3 of H1130 show two schemes for feeding and equal, lengthen, r.f. voltage to the distribution system's phases. The choice between the series tuned and parallel tuned circuits is, as mentioned before, one of impedance and proper choice cannot be made, usually, without experiment. It is expected that the parallel tuned circuit will work in most cases, since it presents a high impedance to the line load.

If the 208 volt system is extensive, it may be necessary to run an r.f. line around and couple into the system at several points to insure good coverage. In this case the coupler shown on H1008 together with the scheme shown in Fig. 1 on H1130 will probably work quite well.

Coupling to the D-C Mains

Coupling to d-c circuits is similar to coupling to single phase a-c circuits. Usually d-c is run using the three wiring system, and so Fig. 1 of H1130 applies. D-c power circuits usually do not carry r.f. very far and so should not be relied upon to do more than carry the r.f. signal around in one building. Thus, in spite of the fact the d-c power may be generated at one point it is best to run r.f. lines to each building and couple into the d-c wiring in each building.

R.F. Lines Coupling Box

A simple and effective method of installing the components required for coupling to building lighting systems is shown on H1117. The installation of this coupling box should be made at a central point in the lighting system to assure equal distribution of r.f. to all circuits. In most cases the building fuse box will be the best place to couple in as here both "hot" sides of the 115/230 volt line be found. In all cases a licensed electrician should make the connections from the fuse block to the hot sides of the wiring, so that the installation will meet all Underwriters standards and conform to the insurance company's requirements.

A similar box should be used when coupling to three phase a-c lines, with the only possible difference being that if all three of the three phase lines are being coupled then three fuses and three capacitors should be installed in the box. Similarly, in small buildings having only 115 volt two wire service only one fuse and capacitor are required.

Note that on drawing H1117 that a 6 ampere fuse is specified. This is not a critical value; in fact, a smaller value should be used whenever available, but never a larger value. If the capacitor does fail the fuse should be low enough in rating so that it will blow, in spite of the fact that the r.f. line and coupling device might show a fairly high d-c resistance to ground (this resistance determines how much power current flows if the coupling capacitor should fail).

Most manufacturers have a two ampere plug type fuse available, although electrical supply houses do not always stock this value. Do not use slo-blowing type fuses intended for motor starting applications, even though rated less than 6 amperes. The r.f. line may be badly overheated during the time required for this type of fuse to blow.

Substitution of the type of fuse block may be made to accomodate 125 volt cartridge type fuses which are made in values as low as 1 ampere. It is recommended that this be done if the 1 ampere or similar rating cartridge fuses are available.

12/2/47

The voltage rating of the capacitors is important and the value selected, 2500 volts d-c working, has a safety factor of seven, which meets all the codes. However, in many cases 1200 volt d-c working capacitors may be used. By changing the value of the capacitor between the limits of .001 mfd. and .01 mfd. the amount of signal fed into the building may be varied to suit individual requirements.

R.F. Trap for Low Voltage Distribution Systems

Occassionally there are buildings in which reception should not be permitted which are connected to the same 115/230 volts distribution circuits as buildings to which the signal is to be fed. When this is the case a watt-hour meter is usually connected in each building which will, to some extent, provide a choking action to the r.f. signal. However, this action is not great enough to prevent signals of substantial amplitude from leaking into the building where reception is not desired, and it becomes necessary to provide a network which will act as a good choke.

Such a network is shown on F1026 including typical constants. The wire size will be determined by the lighting load, the data given being sufficient for a building having a 15 ampere watt hour meter or smaller. The effectiveness of the choking network may be determined in the laboratory by measuring the db. loss between the choke and ground by using a signal generator and r.f. voltmeter. All installation work of the completed unit must be made by a licensed electrician.

Similar chokes are available commercially; they are intended primarily to prevent interference from large electrical machinery but by connecting them in the circuit in the opposite sense they will prevent r.f. from feeding back out of the building wiring. If the use of an r.f. trap is contemplated it is suggested that the problem be presented to the Technical Department for further information on commercially available units.

Coupling Between A-C Distribution Lines

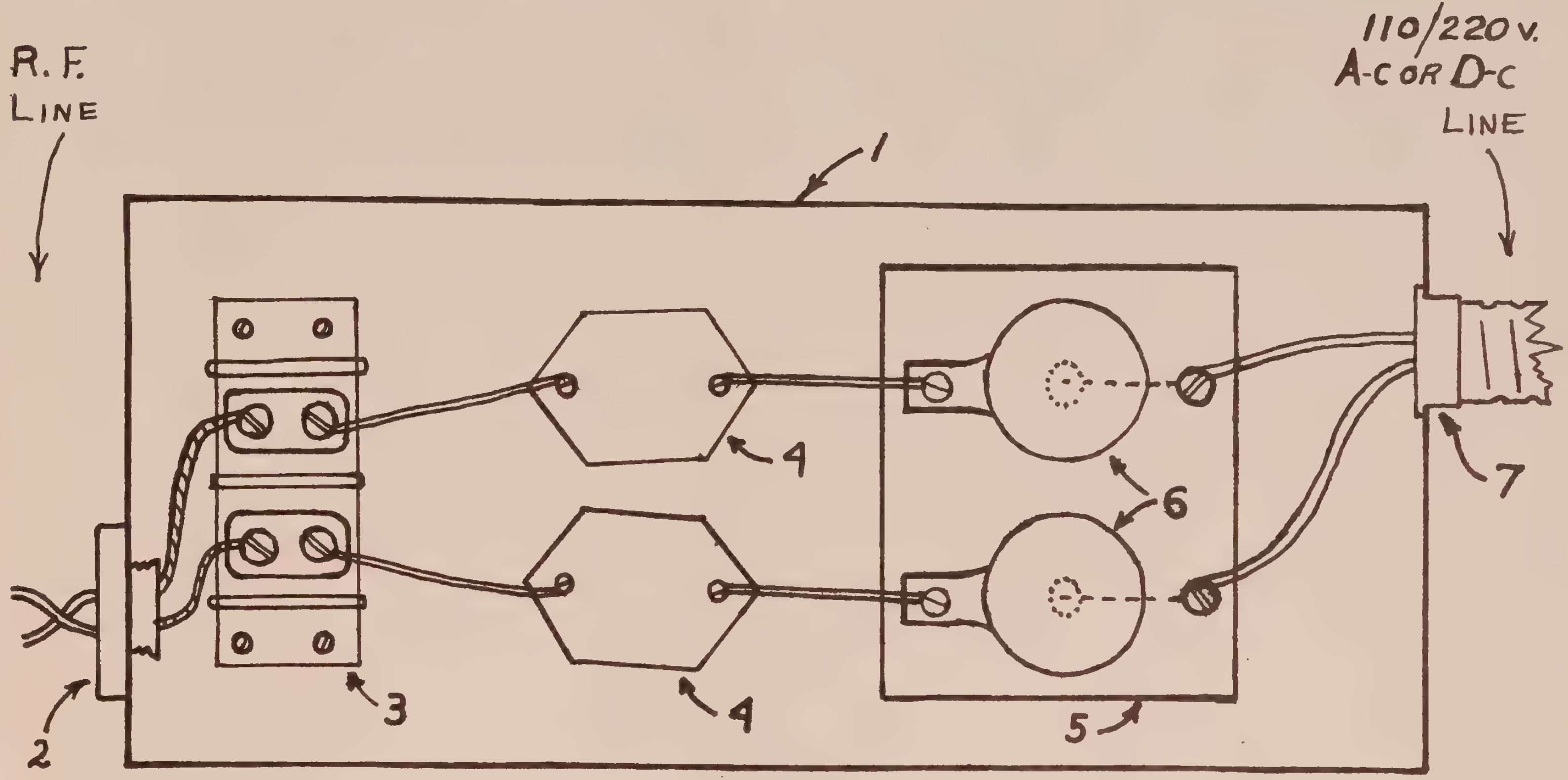
In some instances when planning an r.f. distribution system it will be difficult to find a way to run an r.f. line from the transmitter to each group of buildings which are to be covered by the system. For instances, local restrictions may prevent erecting overhead lines, and no underground tunnels or conduits can be found to use for installing the r.f. line. In this case a solution may be found by using short r.f. lines to tie two or more a-c distribution systems together. Such lines may only have to run between two adjacent buildings, and if necessary can be installed in a trench about two feet deep. (Refer to page TI-3103).

When using this method, r.f. is fed into the a-c wiring feeding one group of buildings, and then at some convenient point an r.f. line is installed to feed some of this r.f. to the a-c wiring feeding another group of buildings.

The elementary method to accomplish this purpose is to run a twisted pair transmission line between two adjacent buildings that are on separate a-c systems and couple the transmission line at both ends through capacitors and fuses to the a-c wiring. In this case the amount of transfer of energy from one system to the other can be controlled by the size of the coupling capacitors used.

A more satisfactory arrangement which is more flexible and results in a greater transfer of energy may be obtained by inserting identical parallel tuned circuits across the transmission line at each end, and link coupling at each end through capacitors and fuses to the 115/230 volt a-c power circuits. The parallel tuned circuits will be as shown on B1098; the inter-

H 1117



MATERIAL LIST

Part No.	Quan.	Description
1	1	9" x 4½" x 3" Cut Out Box
2	1	Porcelain Grommet
3	1	Jones Type 2-142 , 2 terminal Barrier Strip
4	2	C. D. Type 9 Mica Capacitors 2500v d.c. wkg. .001 to .01 mfd. (determines amount of coupling).
5	1	Type 1935 or 2935 Cut-Out Block
6	2	6 amp. line fuse
7	1	BX or Conduit Clamp

Note:

1) Use smallest rating fuse obtainable, but not less than 1 ampere.

2) Cartridge or Little-fuse fuses and blocks may be used. Two Type 3AG, 1A, Cat. 312001 Littlefuses and two Cat. 351001 fuse holders are suitable.

TITLE R.F. LINES COUPLING BOX ASSEMBLY

BEGUN BY H. B. Barlow, April 14, 1947 FINISHED BY H. B. Barlow, April 15, 1947	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H 1117

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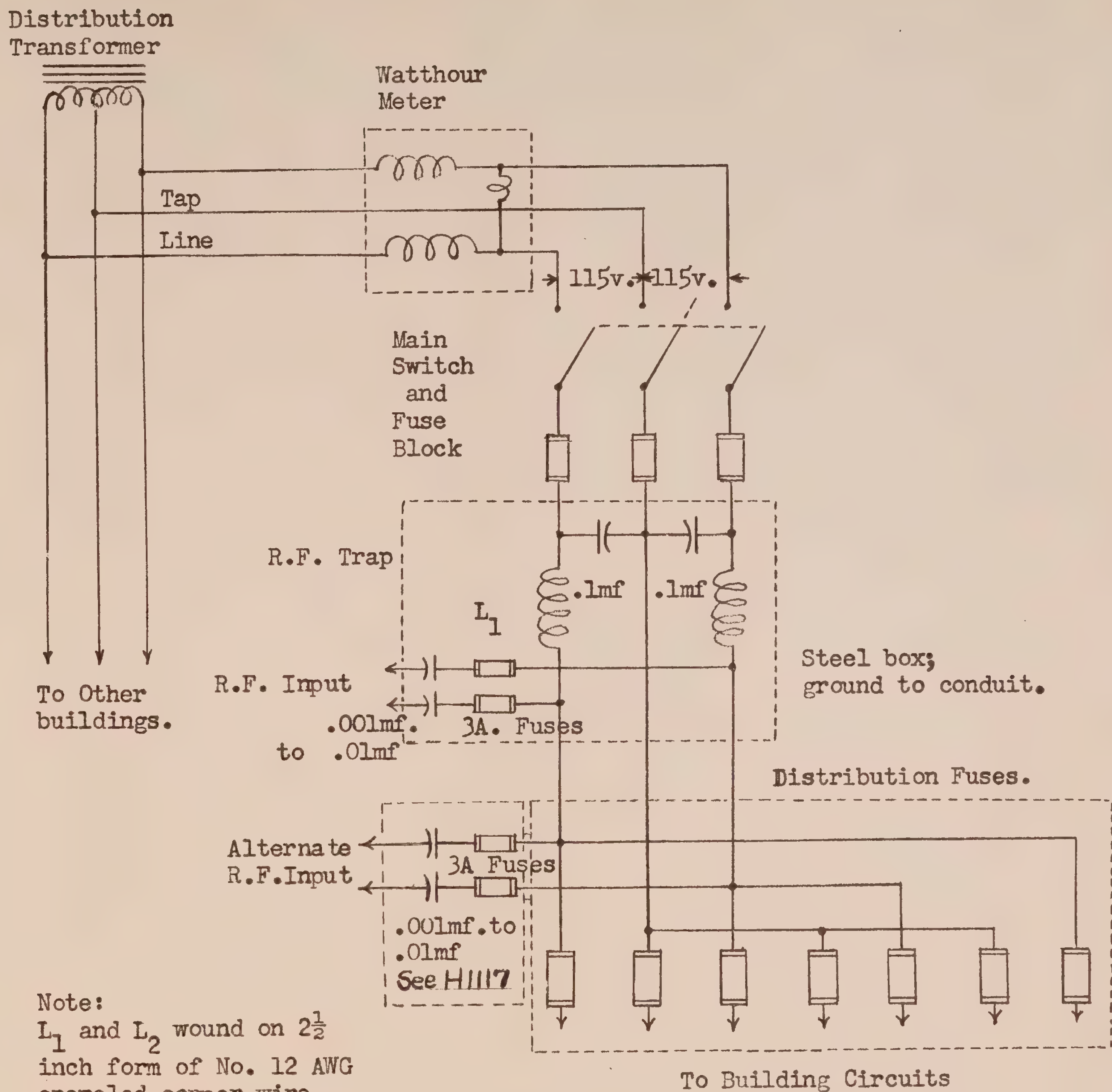


Note:
L_1 and L_2 wound on $2\frac{1}{2}$ inch form of No. 12 AWG enameled copper wire.
15 or more turns spaced the diameter of the wire.

Note:
This is a filter circuit rather than a resonant trap, and is designed to reduce level of r.f. on the a-c tap line by at least 30 db.

TITLE R.F. TRAP FOR LOW VOLTAGE DISTRIBUTION SYSTEMS

FILE REF. T15.33

BEGUN BY D.W. Borst Sept 17, 1943		INTERCOLLEGIATE BROADCASTING		H1026		PY
FINISHED BY re-traced D.W.Borst Oct 15, 1945		SYSTEM TECHNICAL DEPT.				HB
REVISED: [1] Oct 15, 1945	[2] Dec 2, 1947					DL
						R
						PRINTS TO

T152 7-7-45

connecting r.f. line should be connected to the two taps on the tank coil. These couplers will insure a maximum r.f. voltage across the interconnecting line at the sending end, and a greater transfer of power to the a-c system at the receiving end than is obtained by using capacitors alone for coupling. The amount of coupling between the two a-c systems can be controlled by varying the size of the coupling capacitors, the position of the links and the location of the taps on the tank coils, all of the usual methods.

If power is being transferred from a single phase a-c circuit to a three phase a-c circuit, the tank circuits should again be used, but the various methods for coupling to three phase power, discussed on page [illegible] should be tried and the one giving the best results should be used.

Linear R.F. Amplifiers

It may be necessary to install a particularly long r.f. line, at the end of which insufficient signal level is obtained to give good reception. If there are no other loads tapped to this line, good reception might be obtained by increasing the power fed in at the sending end. Cases arise, however, when increasing the power fed into the line causes excessive radiation from the line, and then some other method must be sought. It is in this case that the linear r.f. amplifier at the remote end of the line should be considered.

A representative linear r.f. amplifier with coupling circuit and power supply is shown on [illegible], and described in section [illegible]. Amplifiers with any desired power output can be constructed. They cost less than a complete transmitter because frequency control and modulator stages are not required. An r.f. amplifier may be left running continuously since when the transmitter is turned off the r.f. amplifier will also cease to send out a signal. Since the frequency of the r.f. amplifier is the same as that of the transmitter, no trouble will be experienced from interference, as might be the case if two transmitters are used.

The output of the linear r.f. amplifier may be used to feed any number of buildings, using a transmission system similar to the one which the transmitter feeds. Thus, if the campus is divided into two or more main areas which can be connected together by means of r.f. lines, it may prove a good plan to install a transmitter to cover one area and one or more r.f. amplifiers to cover the other, rather than try to do the whole job with one transmitter and run the risk of excessive radiation from the larger transmitter and the r.f. lines system.

TYPICAL RECOMMENDED R.F. DISTRIBUTION SYSTEM

General

Drawing D2010, which follows this page, shows several of the commonly used ways of interconnecting the circuits discussed on pages TI-3151 through 57 and shown on H1129, H1008, H1130 and H1117.

You will note the transmitter feeds an auxiliary coupler, tank circuit #1. Load "A", which is fed by this transmitter, is assumed to be at a considerable distance from the transmitter and so a single long r.f. line is used to feed it in order to minimize standing waves on this line, and resulting radiation.

The rest of the drawing shows a more complicated set-up with a long line running to Load "B" at which point another auxiliary coupler (tank circuit #3) is installed which feeds Load "B" through tank circuit #4 and the associated coupling capacitors and fuses, and also from this point Loads "C" and "D" are fed.

Both Load "C" and Load "D" are assumed to be some distance from Load "B", and so a long r.f. line is shown with a tank circuit at each end. By installing these tank circuits, standing waves are kept to a minimum on these long lines, thus keeping radiation low.

You will appreciate that the auxiliary coupler at Load "B" (tank circuit #3) was used in place of the Intermediate Coupler shown at the bottom of drawing H1129. This Intermediate Coupler may be used if you desire to tap a single load into an r.f. line. However, the scheme shown on D2010 will probably be found useful in more cases, since quite frequently it is desired to feed a group of buildings all some distance from the transmitter. In this case a long r.f. line should be run from the transmitter to one of the buildings in the group being fed, at which point tank circuit #3 should be installed and the various buildings fed in the manner shown for Loads "B", "C" and "D". You will appreciate at once that if you desire, more than three loads can be fed from tank circuit #3.

Adjusting Signal Level in Buildings

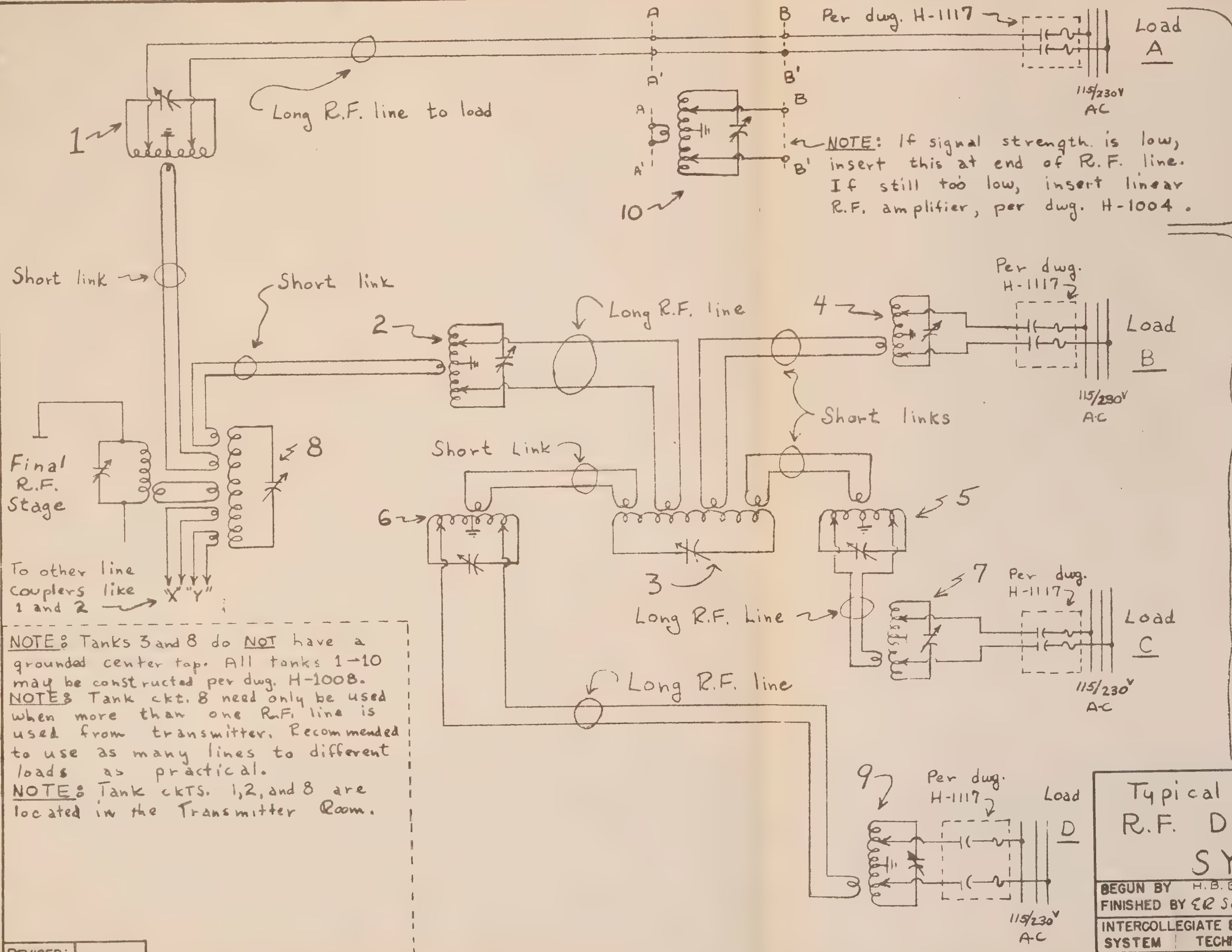
You will find that the circuit arrangement shown on D2010 provides a number of ways of conveniently adjusting the signal level in each building you are feeding. For Load "A" the taps on tank circuit #1 should be adjusted to regulate the signal level. For Loads "B", "C" and "D", make similar adjustments on tank circuits #4, #5 and #6, respectively.

Another way of adjusting the signal in each building is to vary the size of the r.f. coupling capacitor. You will find this fact briefly mentioned on the fourth line on page TI-3156, also on drawing H1117. Select a value in the range of .001 mfd. to .01 mfd. The large the value, the greater amount of coupling. There is no good rule to follow when making this selection. If the building is small, such as a frame dwelling, or if it is very close to the transmitter, use .001 mfd. If the building is a large dormitory, or some distance from the transmitter, use .01 mfd.

You will find it quite important to properly adjust the signal fed to each building. The a-c wiring in some buildings radiates more than in others, and so the signal fed into some buildings (the ones which radiate more) will have to be held down. Buildings which have open type wiring will radiate more than buildings which have the wiring in conduit. If you have adjusted your lines properly you will find that most of the radiation from your r.f. system will be radiation from building wiring and the a-c wiring which runs away from the building.

2/21/49

B 2010



Use this system when only one load has to be fed.

Use this scheme where R.F. must be tapped off and then fed to one or more loads.

NOTE: Tanks 3 and 8 do NOT have a grounded center tap. All tanks 1–10 may be constructed per dwg. H-1008.
NOTE: Tank ckt. 8 need only be used when more than one R.F. line is used from transmitter. Recommended to use as many lines to different loads as practical.
NOTE: Tank ckts. 1, 2, and 8 are located in the Transmitter Room.

REVISED:

Typical Recommended R.F. DISTRIBUTION SYSTEM	
BEGUN BY H.B. BARLOW, JR	OCT. 21, 1948
FINISHED BY E.R. Schiffmacher	Nov. 30, 1948
INTERCOLLEGIATE BROADCASTING SYSTEM — TECHNICAL DEPT.	B 2010

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T150 6-20-45

Engineering Note
Number 16

April 11, 1948

Remote Audio Line Sending and Receiving Connections

Immediately following page TI-3157 in the Third Edition of the IBS Technical Data Book you will find three drawings pertaining to remote audio line connections. You will find these diagrams useful when setting up to receive remote broadcasts, or when sending your program signals by audio line to some remote point.

E1110 Line Isolating Transformer and Equalizing Circuits

These circuits are indicated on E1109 and E1119 and are detailed on E1110.

E1109 Block Schematic - Network Receiving Connections

This drawing illustrates the preferred way of bringing in any remote program, expecially one from a distant point, and the use of a booster amplifier like E1099 or E1111.

E1119 Block Schematic - Network Sending and Receiving Connections.

An extension of E1109 of greatest interest to stations originating programs over a regional or national network. More detailed written information can be obtained by ordering Technical Memo No. 12, IBS form T163.

David W. Borst

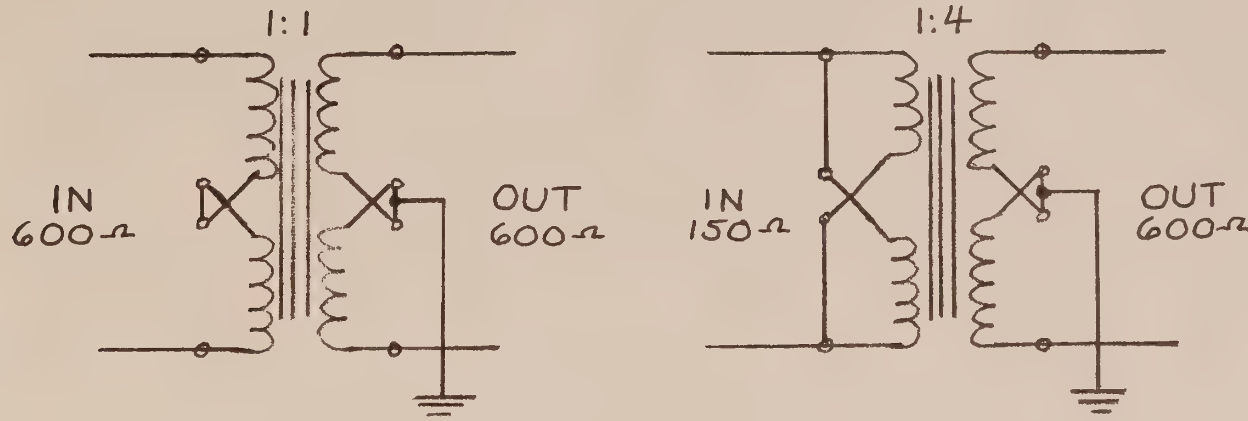
Engineering Notes are issued from time to time by the Engineering Department, Intercollegiate Broadcasting System, WKCR Hamilton Annex, Columbia U., New York 27, N.Y.

It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for handy future reference.

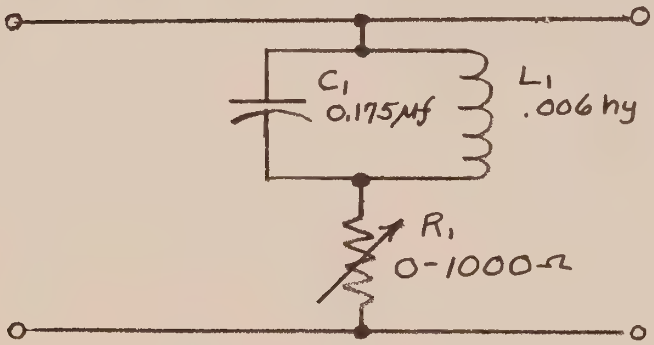
Engineering Department File Number T15.34.

If your station does not have the Third Edition of the Technical Data Book write us about it.

ISOLATING TRANSFORMER



600Ω EQUALIZER



RESONANT FREQUENCY
5000 CYCLES, APPROX.

ADJUST R_1 FOR DEGREE OF EQUALIZATION REQUIRED

TITLE LINE ISOLATING TRANSFORMER AND LINE EQUALIZING CIRCUITS

FILE REF.: T15.34

BEGUN BY D.W. Borst Jan 7, 1947 FINISHED BY D.W. Borst Feb 26, 1947	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1110
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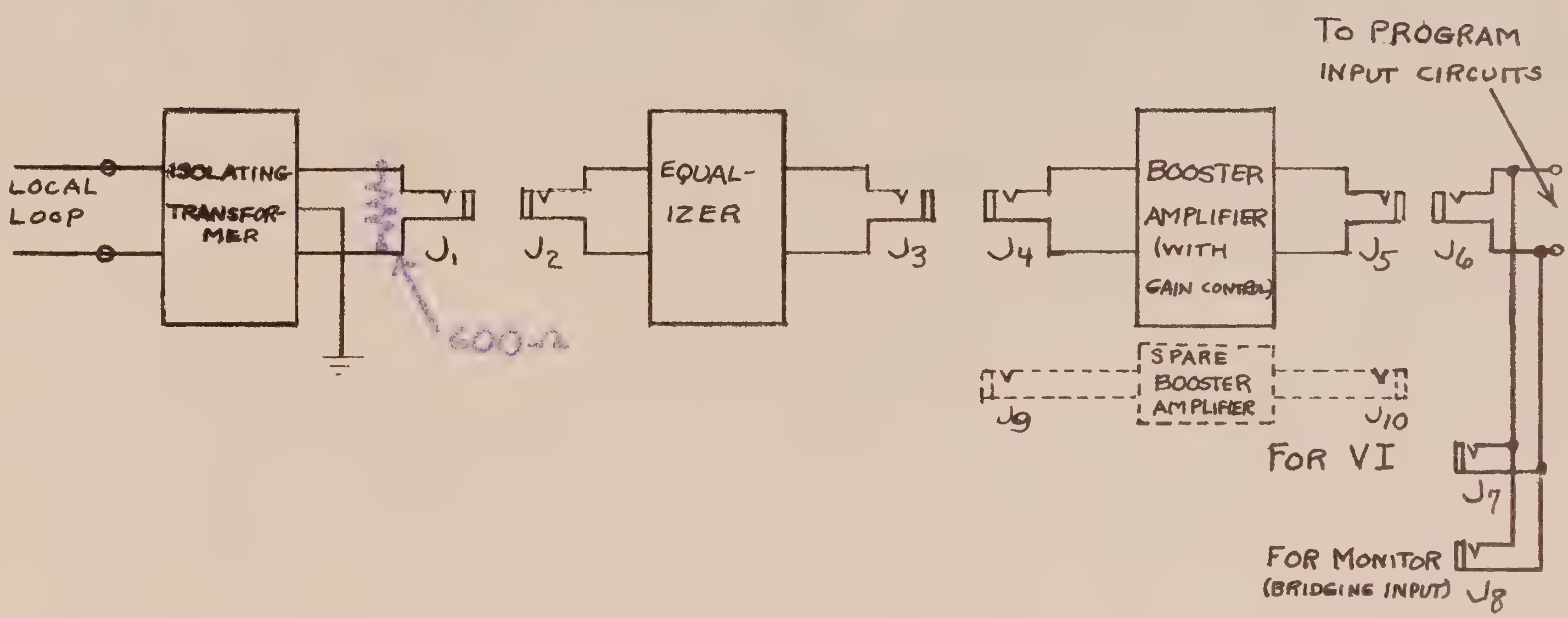
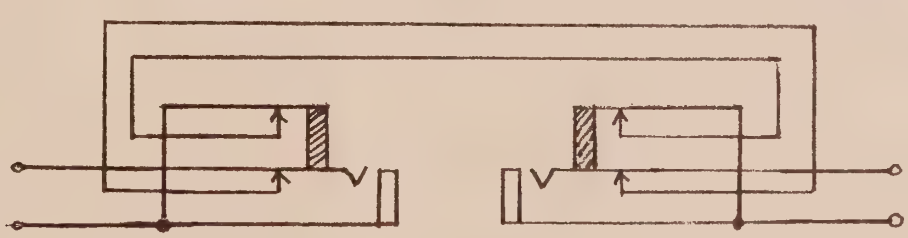


NOTES:

1) JACKS J_1-J_2, J_3-J_4 AND J_5-J_6 SHOULD BE NORMALLY PATCHED TOGETHER. TWO-CIRCUIT, CIRCUIT OPENING JACKS MAY BE USED, WIRED TO NORMALLY ESTABLISH THE ABOVE CIRCUIT. SEE DETAIL.
2) BOOSTER AMPLIFIER MAY FEED A MATCHING TRANSFORMER, OR MAY BE TERMINATED IN 600Ω AND BRIDGED. INPUT TO BOOSTER AMPLIFIER SHOULD TERMINATE EQUALIZER IN 600Ω IN SIMILAR FASHION.
3) PROGRAM INPUT CIRCUIT MAY BE A JACK ON REMOTE LINE PATCH PANEL, A CHANNEL OF THE MASTER MIXER, OR A POSITION ON THE PROGRAM CHANNEL AMPLIFIER INPUT SELECTOR SWITCH.
4) J_7 AND J_8 MAY BE REPLACED BY POSITIONS ON SELECTOR SWITCHES.
5) SPARE BOOSTER AMPLIFIER IS RECOMMENDED.

CIRCUIT OPENING JACK DETAIL



TITLE BLOCK SCHEMATIC - NETWORK RECEIVING CONNECTIONS

FILE REF.: T15.34

BEGUN BY D.W. Bnot Jan 7, 1947
FINISHED BY D.W. Bnot Feb. 26, 1947

INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.

H1109

REVISED: Feb. 2/47

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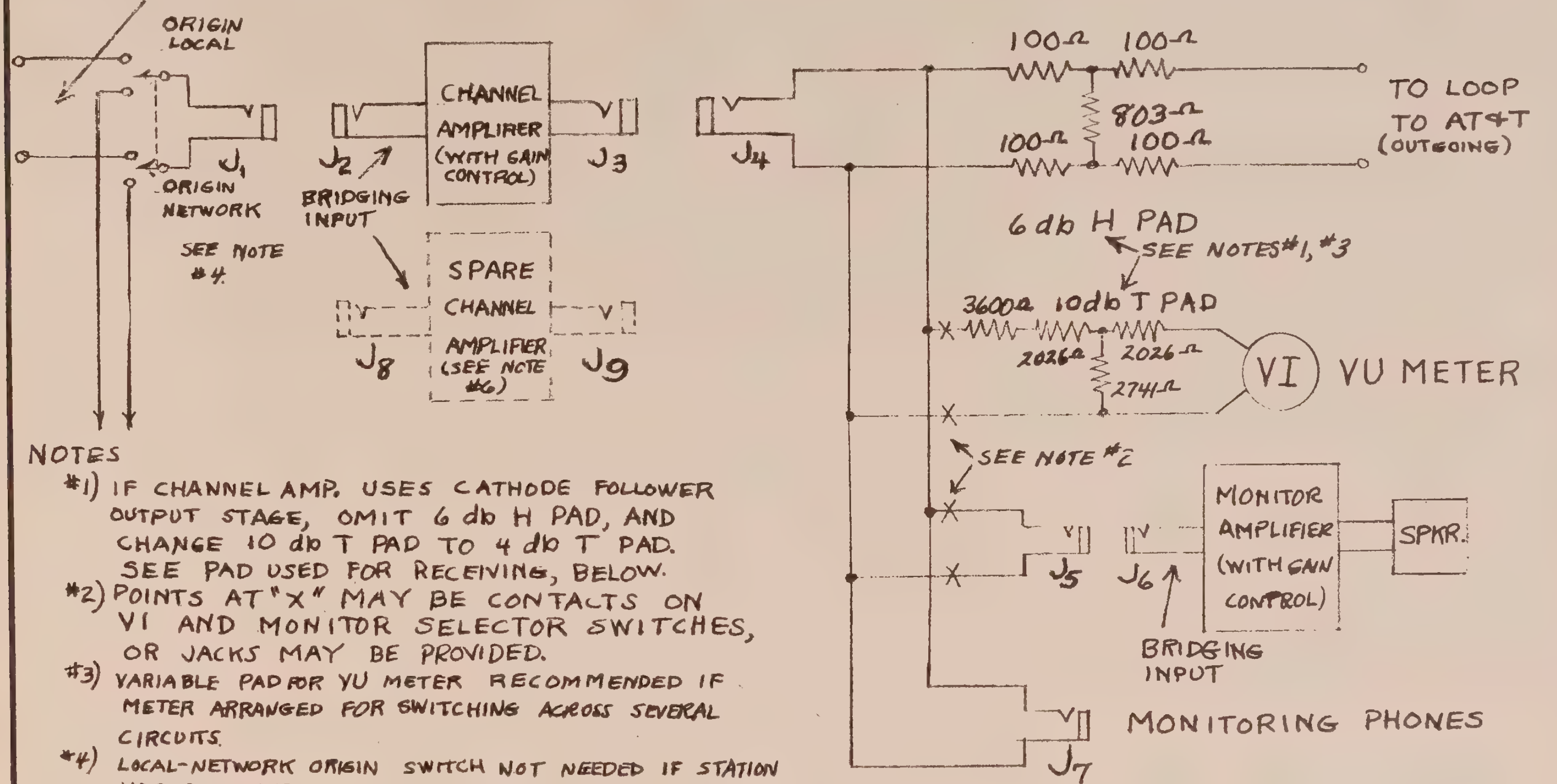
PRINTS TO

T152 7-7-45

SENDING CONNECTIONS



NOTES

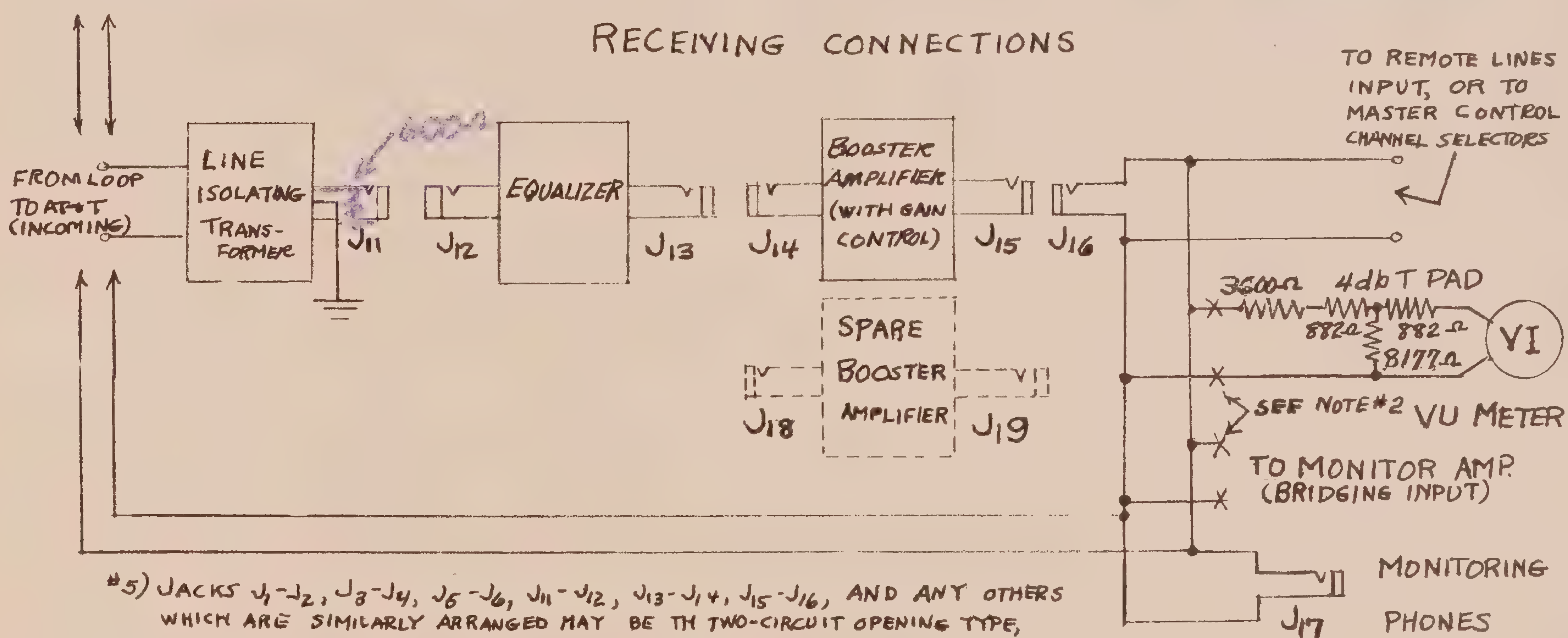
\#1) IF CHANNEL AMP. USES CATHODE FOLLOWER OUTPUT STAGE, OMIT 6 db H PAD, AND CHANGE 10 db T PAD TO 4 db T PAD. SEE PAD USED FOR RECEIVING, BELOW.

\#2) POINTS AT "X" MAY BE CONTACTS ON VI AND MONITOR SELECTOR SWITCHES, OR JACKS MAY BE PROVIDED.

\#3) VARIABLE PAD FOR VU METER RECOMMENDED IF METER ARRANGED FOR SWITCHING ACROSS SEVERAL CIRCUITS.

\#4) LOCAL-NETWORK ORIGIN SWITCH NOT NEEDED IF STATION HAS A MASTER CONTROL.

RECEIVING CONNECTIONS



\#5) JACKS J1-J2, J3-J4, J5-J6, J11-J12, J13-J14, J15-J16, AND ANY OTHERS WHICH ARE SIMILARLY ARRANGED MAY BE TH TWO-CIRCUIT OPENING TYPE, WIRED TO NORMALLY ESTABLISH THE CIRCUITS SHOWN.

\#6) SPARE AMPLIFIERS RECOMMENDED.

\#7) IT IS ASSUMED THAT EXISTING CIRCUITS PROVIDE 600Ω LOADS FOR OUTPUT OF PROGRAM MIXER AND BOOSTER AMPLIFIER.

TITLE BLOCK SCHEMATIC-NETWORK SENDING AND RECEIVING CONNECTIONS

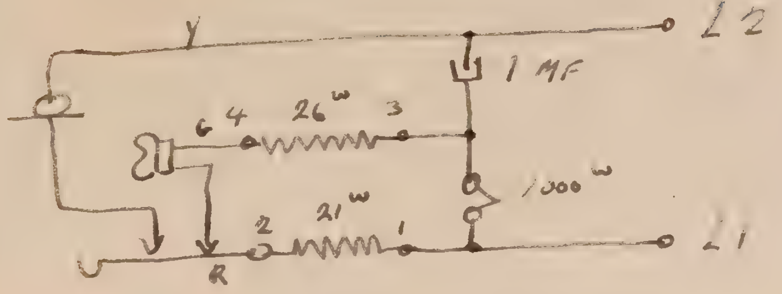
FILE REF: T15.34

BEGUN BY DWBort Feb 25, 1947	INTERCOLLEGIATE BROADCASTING	H1119	HT PY DL R
FINISHED BY DWBort Feb 27, 1947	SYSTEM TECHNICAL DEPT.		PRINTS TO
REVISED: 1 Sept 20, 1947			

T152 7-7-45

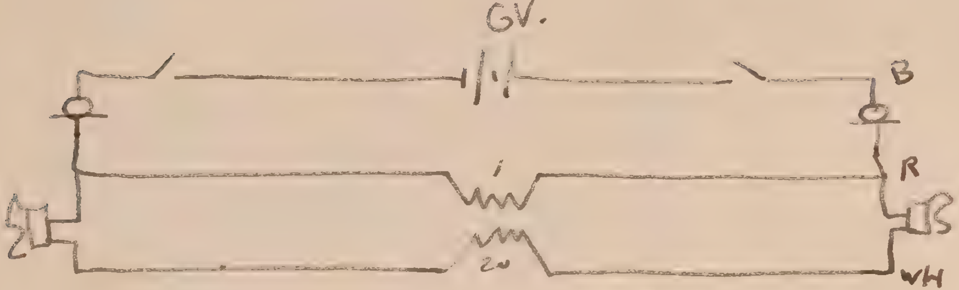
BELL SYSTEM TYPE TELEPHONE SET.

"STANDARD BOOSTER"



"Seek ye first the kingdom of God, and his righteousness." Matt. 6:33

Circuits for Handsets:



1:20 ratio X former
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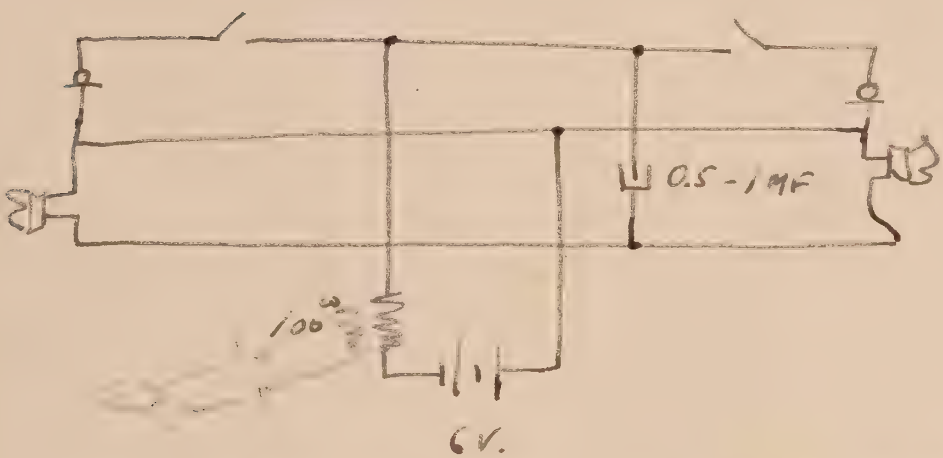

THIS YOU COULD EXPAND TO 3, 4, 5 or more phone sets as the demand arose.

Engineering Note
Number 1

March 20, 1947

GENERAL ELECTRIC VARIABLE RELUCTANCE PICKUP

DESCRIPTION

The General Electric variable reluctance pickup is one of the best reproducers in the low cost field for use on commercial pressings as well as on transcriptions. Properly installed its performance compares favorably with other pickups of far greater cost. It features a permanent saphire stylus, low record wear, low distortion and low surface noise on even old worn out discs.

The pickup may be purchased separately through radio dealers and the General Electric Supply Corporation. Either of two catalog numbers may be used: DL-IRM6C or RPX-101A. The latter is a replacement part for the Model 417 Musaphonic receiver. General Electric bulletin ESD-13 describing this pickup is available through your supplier or from the Electronics Department, G. E. Co., Thompson Road, Syracuse.

APPLICATION

A) PICKUP ARM

The pickup will fit with little or no modification in place of many of the popular crystal cartridges, such as the Astatic L, L-70, LP and M series. Since the pickup requires only 3/4 to 1-1/4 ounces pressure, it may be necessary to counterbalance some pickup arms to reduce their pressure. If the arm is designed for a low pressure crystal pickup it can probably be used without change. Thus the arms used in the Astatic Models FP-8, FP-18, FL-48, BP-16, 400, 507, 508, and 510 pickups are all suitable. Only the Model BP-16 and 400 arms are long enough to play 16 inch diameter transcriptions. The Model 400 arm is preferred.

Similar pickup arms made by Shure and others will also be satisfactory.

B) PRE-AMPLIFIER

The open circuit output voltage of the pickup [illegible] at normal recording level, [illegible] if a crystal pickup is being replaced. The pickup can be fed [illegible] a microphone preamplifier but [illegible] characteristics some amplification is necessary. A [illegible] circuit has been designed [illegible] for commercial [illegible] [illegible]

response, to reduce turntable rumble present in the average turntable. Also, when playing 33-1/3 transcriptions cut to the NAB or orthophonic recording characteristics it may be necessary to modify the high frequency response of the preamplifier.

The pickup introduces negligible distortion due to self-resonance or intermodulation; and so when designing an equalizer circuit it is only necessary to consider the characteristics of the recording apparatus. Usually an increase in the pickup output of 6 db. per octave starting at 500 cycles and extending downward, and some means of attenuating the high frequency response above 3000 cycles and at the very low frequencies below 100 cycles is required.

REFERENCES

General Electric Bulletin ERD-13.

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Transactions of A.I.E.E. - March 1946, page 159

The Reproduction of Disc Recordings - John D. Goodell
Radio News - Jan. 1947, page 3 of Radio Electronic Eng. Dept.

The Reproduction of Disc Recordings - John D. Goodell
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Crystal Pickup Compensation Circuits
Electronics - Nov. 1945, page 128.

Standard Pre-emphasis Curves
Communications - May 1943, page 62.

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Communications - August 1942, page 20.

Tracking Angle in Phonograph Pickups
B. B. Bauer, Electronics - March 1945, page 110

David W. Borst
Technical Manager

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Technical Department Engineering File Number T15.41.

Engineering Note
Number 3

March 29, 1947

APPLICATION NOTES ON G.E. VARIABLE RELUCTANCE PICKUP

These notes supplement those given in Engineering Note No. 1, pages TI-4251 and 52. They are written after a week's trial operation of a variable reluctance pickup at WRUC, Union College.

The pickup was installed in an Astatic FP-18 arm. The pickup came with two No. 3-48 screws for mounting. These had to be removed and replaced with the two [illegible] screws, [illegible], which originally held the LP-21 cartridge in the FP-18 arm. To remove the 3-48 screws, it was necessary to remove first the dust cover from the pickup assembly, and then force the screws past the brass chassis plate which mounts the operating parts of the pickup. This could not be done until some of the chassis material had been cut away with a pair of diagonal wire cutters. Otherwise, the GE pickup replaced the LP-21 cartridge perfectly.

The spring tension in the arm base was increased some to reduce the stylus pressure, but this did not have any appreciable effect on the performance of the GE pickup.

A preamplifier in accordance with the circuit in GE Bulletin ESD-13 was built on a small chassis with a self-contained power supply. A 6J5 cathode follower stage was added to provide a low impedance output. The output level from the preamplifier was about 1.5 volts. A self-contained power supply on the preamplifier is not recommended, as when the pickup was connected a hum was observed which [illegible] the preamplifier was disconnected. A power supply separate from the preamplifier would reduce the magnitude of stray magnetic fields and currents induced by them in the chassis. This would probably prevent the hum which was observed.

The preamplifier proved to have insufficient low frequency response. The corrective filter in the preamplifier should be modified to give a more steeply rising bass characteristic. A variable 5000 ohm resistor in series with a fixed [illegible] ohm resistor placed across the pickup provides an adjustment for reducing surface noise on particularly poor recordings.

The pickup performed very well, both in regard to reduction of surface noise, and improving the performance of [illegible]. It is recommended that every station in the system consider its use.

[illegible]

[illegible]

[illegible]

[illegible]

The reception of frequency modulated signals requires the use of a special receiving circuit designed to receive signals having a 150 kc bandwidth and a frequency range between 88 and 108 mc. In addition to the conventional converter or input unit found in the usual superheterodyne built to receive this range of frequencies the [illegible] must employ stages of intermediate amplification at a higher than normal frequency, one or two limited output stages of amplification at the same i.f. frequency (limiters), and a discriminator in place of the conventional detector. The receiving circuits which achieve the high quality and low noise level characteristics of FM are all incorporated in the stages preceding the audio amplifying equipment. For this reason, it is possible to build a converter or tuner unit which may be used to receive and detect an FM signal and the output of this device may then be amplified by conventional means. The output of most converters now on the market is usually comparable to that of a crystal phonograph pickup, so no unusual problems are encountered in wiring them to a conventional amplifier.

The rebroadcasting of frequency modulated signals by college radio stations is being done on a considerable scale by colleges within the service area of FM stations. Naturally any program material so obtained should be rebroadcast with the greatest possible fidelity and reliability consistent with the use of FM, and so it becomes the technical staffs of such stations to install the best possible equipment for such service. Certain refinements in the equipment and techniques used by the general public seem indicated when [illegible] is undertaken.

The Receiver

First, the selection of the receiver should be given careful thought. Probably the commonest type of equipment is purchased, [illegible] low power audio [illegible] and large cabinet of a console set [illegible] mounted in a studio control room, only adding to the [illegible]. The receiver should have [illegible] intermediate frequency [illegible] considerable intermediate frequency amplification. [illegible]

[illegible]

Receiving Antenna

In addition to a good receiver an adequate antenna is needed. If the receiver is located near an FM station, a simple folded dipole with parallel wire feeders will prove adequate. This [illegible] may be made of 300 ohm polyethylene "twin-lead." [illegible] pieces of the "twin-lead" about five feet long should be [illegible] at both ends. One conductor should be cut in the middle and the two ends soldered to the ends of the "twin-lead" going to the receiver.

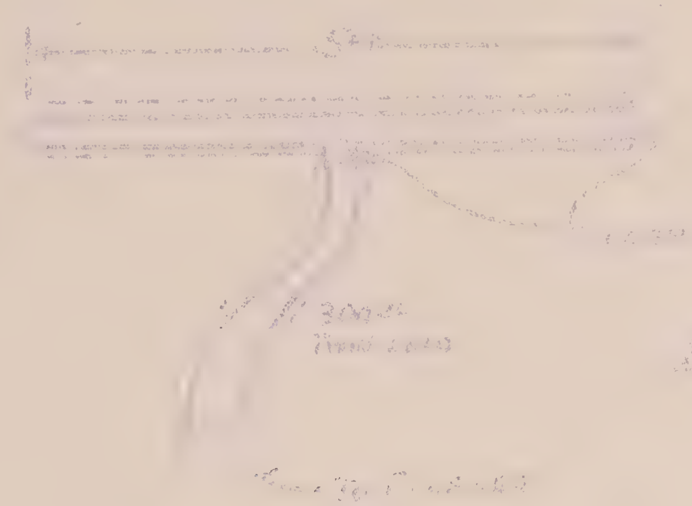

Fig. 2

This antenna should be erected as high as possible, and be well clear of any surrounding structures, especially those which come between the receiving antenna and the antenna of the station which is to be relayed. The receiving antenna should be located in the plane of polarization of the transmitter's waves, which is generally horizontal. The dipole should be run at right angles to the direction of the station to be received. For colleges located at some distance from any FM transmitter it may be necessary to erect a directional antenna. This may consist of reflector and directors as well as the main antenna element.

Tuning Indicators

The conventiona "magic eye" tuning indicator can only be successfully employed on an FM set if it is properly aligned. Some more positive means of indicating correctness of tuning is highly desirable. For one thing, it is difficult to tell by ear when the receiver is precisely tuned in. There is an appreciable tuning band over which the tuning dial may be adjusted and which will give fairly good quality output. However, if a set is not exactly tuned in, distortion may be apparent during passages resulting in a full modulation swing of 150 kc. at the transmitter, while other passages resulting in less swing will not be distorted. Furthermore, local stations on an FM set may be heard at three closely spaced positions of the tuning dial. Only one of these settings is the proper one, but without an indicator the set might be tuned to one of the others by mistake.

Some FM receivers have been designed with a tuning eye which measures, in effect, the grid bias of the limiter tube. This bias varies directly with the signal input to that tube, and is greatest when tuning the receiver at the resonance peak of the input transformer to the limiter. However, this point is only a [illegible] of the point of [illegible] performance, which is [illegible] of the discriminator input transformer. If the receiver is only slightly misaligned, these two resonance points are often an appreciable distance apart.

The best tuning indicator is a sensitive volt meter or galvanometer which measures the direct current output of the discriminator. The discriminator is a circuit which produces a d.c. voltage whose magnitude and polarity depend upon the direction and amount of frequency modulation of the received carrier into audio signals. The carrier of the received signal will produce a voltage output from the discriminator provided the receiver is not tuned in exactly. Because this voltage output has a different polarity depending upon whether the receiver is tuned to one or the other side of the carrier frequency, it is impossible to use an electron beam indicator. However, a high impedance, zero center d.c. voltmeter will measure this voltage with negligible effect upon the quality of the received signal. The meter should be connected between the two cathodes of the discriminator which is usually a 6H6 tube. Provided the meter has been adjusted to the zero center with no applied voltage, then when the FM receiver is tuned to a station the meter will again read zero when the station is properly tuned in. An even rocking motion of the tuning dial on each side of the station should cause the tuning meter needle to swing from one side of zero to the other. If the amount of swing does not increase linearly over a considerable percentage of detuning each side of the station, then either the set has been tuned to the wrong dial setting, as explained before, or else the discriminator has been improperly lined up.

Once the set has been properly tuned and is operating, the tuning indicator should be checked occasionally. There may be a tendency for the FM receiver to drift as it warms up during operation. This drift may be detected on the tuning indicator long before the quality of the received signal is sufficiently impaired to notice it. The receiver may then be re-tuned, the tuning indicator also showing in which direction the tuning should be done, before any impairment in program quality is experienced.

Audio Coupling

The discriminator output of an FM set must be passed through an audio frequency "de-emphasis" network to compensate for high frequency "pre-emphasis" inserted in the FM transmitter to improve the signal-to-noise ratio. This network generally consists of a resistor in series with the output and a condenser shunted across the output. This circuit will not function properly if shunted by an impedance less than one megohm. Long cables, loud-speakers, etc., may not be connected directly to the output.

The most satisfactory arrangement for connecting to the output of an FM tuner is to use a coupling tube. This should be a cathode-coupled stage or a tube with low output impedance and high input impedance (pentode with low-value plate load). This stage should be carefully adjusted so that it does not introduce distortion.

Provision should be made for monitoring the FM signals before they are placed on the air. Headphones connected to the low-impedance output of the coupling tube are satisfactory. A position on the monitor-amplifier selector switch bringing the coupling tube output will also do, although a headphone jack should still be available so that both the campus station program and the FM program coming up may be monitored simultaneously.

Additional Considerations

Perhaps, with a source of high fidelity program material about to go into operation, it would be wise to make a check of the entire studio and transmitter audio circuits. If it is felt that any circuit is not up to maximum operating efficiency, it should be repaired at once. If, once the FM translator is in operation, there is a noticeable difference between direct FM reception and the reception of FM via the college station, then steps should be immediately taken to remedy the trouble.

(Signed) William R. Hutchins
(Title) Technical Advisor

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Technical Department Engineering File Number T14.45.

[illegible]
Number 1

October 31, 1947

FM RECEIVER MODIFICATIONS

General

Several modifications can be easily made to FM tuners to better adapt them for relaying FM programs over campus stations, as is often done either as a means of extending the program schedule of the station, or to obtain a high fidelity signal for test purposes. These modifications include adding a cathode follower stage to give a low impedance output characteristic to the tuner and adding an accurate tuning indicator.

In addition, many stations have older FM tuners which do not tune to the new FM broadcast band (88 to 108 mc.). These receivers can often be modified rather easily to tune the new band.

Many stations in the System have the General Electric JFM-90 tuner which tunes the old band, has high impedance output, and does not have a tuning indicator. Specific instructions for modifying this receiver will be given in this article; similar procedure can be followed in the case of other tuners of old and new design.

Addition of Low Impedance Output

Low impedance output is achieved by adding a triode stage connected as a cathode follower amplifier and having an output impedance of between 400 and 500 ohms. This stage is not capable of driving a 600 or 500 ohm line at the standard level of plus 8 VU (old 0 db.), but it can be used to feed into a booster amplifier having either 600 ohm or bridging input, and ordinary audio wiring may be used to carry the signal without noise pickup, cross talk, of impairment of audio fidelity. When this stage has been added, the FM tuner can be terminated on the incoming lines patch panel, and the booster amplifier used for bringing in remote broadcasts can also be used to feed FM to the station's audio circuits. Similarly, the FM receiver output may be bridged by the station monitor by providing appropriate switching circuits.

The cathode follower tube may be either the 6C5 or the 6J5. The connections are shown in Fig. 1. In the JFM-90, disconnect the leads from the filter capacitor and remove it from the top of the chassis. By means of a mounting clamp, mount this capacitor underneath the chassis on the back of the front apron. In the hole left by the filter capacitor can, mount an octal socket to accommodate the cathode follower stage. The miscellaneous resistors and capacitors can be mounted on existing lugs and socket terminals beneath the chassis.

The JFM-90 is not provided with a volume control. If one is desired, replace the present a-c power switch with a 500 000 ohm volume control with a-c switch attachment. In providing the shielded wire to run from the volume control to the grid of the 6C5, it will be found that the present shielded wire connecting the phonograph jack to the phonograph switch is just the right length. Inasmuch as the phonograph jack is no longer used, this wire may be so employed.

In order to obtain the correct "de-emphasis" characteristic [illegible] frequency [illegible]

The final step in this modification is to mount a two connection terminal strip on the rear apron of the chassis at the opposite end from the antenna terminals for the output connection of the receiver.

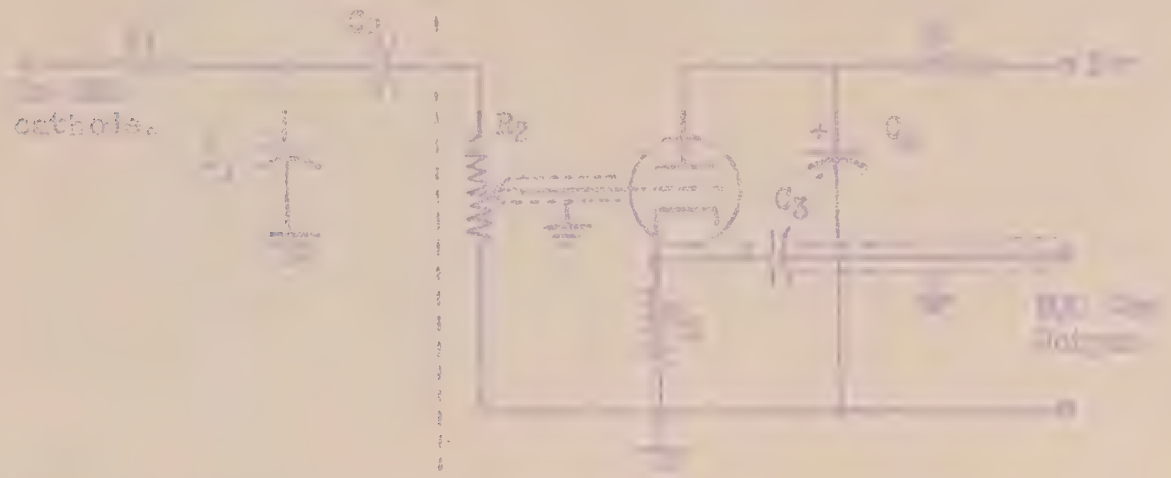


Fig. 1

R_1 100,000 "restorer" resistor, R_{22} in GE diagram of JFM-90.

R_2 500,000 ohm potentiometer, (fixed if gain control not desired).

R_3 2000 ohms 1 watt

R_4 10,000 ohms, 1 watt

C_1 1000 mmf. midget mica installed in place of 220 mmf. capacitor C_{35} in GE diagram of JFM-90.

C_2 .02 mf paper capacitor, C_{38} in GE diagram of JFM-90.

C_3 50 mf. 25 volt dry electrolytic capacitor, small tubular type.

C_4 8 mf. 450 volt dry electrolytic capacitor, small tubular type.

Addition of Tuning Indicator

The best type of tuning indicator for an FM receiver having a discriminator type of detector is a sensitive voltmeter or galvanometer connected between the two cathodes of the discriminator. In the GE JFM-90 the meter should be connected between the point in Fig. 1 marked "To 6H6 cathode" and ground. Preferably, a zero center type d-c instrument should be used, since the discriminator produces an output of both positive and negative polarity. However, an instrument having a conventional scale with the zero at the left end can often be used if the zero adjustment of the meter is turned so the the pointer comes to rest part way up-scale. The receiver can then be tuned to cause the pointer to stay at that particular place on the scale.

A sensitive instrument should be used for the tuning indicator. A 0.5 milliampere (500 microampere) meter has been successfully used; in this case a 100,000 ohm resistor was connected in series with the instrument to convert it to a voltmeter having the proper range. It is important to give this series resistor a high value, and yet get a good deflection of the meter pointer so that accurate tuning is possible. A 100 or 50 microampere instrument will make a much better tuning indicator than a 500 microampere instrument since a higher series resistance value may be used.

For a complete discussion of tuning an FM receiver using this type of tuning indicator refer to the section "Tuning Indicator" which begins on page TI-[illegible].

[illegible]

Convertors employing a vacuum tube oscillator-converter stage have been available for some time which can be used to convert any old band FM set to the new band. Another method employing a 1N34 [illegible] and a few other small parts has been devised which will often work very well, and it is this method which will be described.

The procedure is to couple some of the signal from the FM receiver's local oscillator into an added tuned circuit which is also coupled to the antenna and to the 1N34 crystal. In this way, the 1N34 converts the signals on the new band to signals on the old band, by hetrodyning them with one of the harmonics of the FM set's local oscillator. If the 1N34 is then coupled to the antenna post on the FM receiver, the output of the crystal will be amplified and detected in the usual manner [illegible]. Tuning is accomplished by the regular tuning controls of the receiver. Of course, the dial calibrations do not indicate the frequency of the stations on the new band.

It works out that an ordinary FM receiver of the old type having a 4.3 mc. IF channel will not tune the new band, entirely. The JFM-90, however, will because it is a double-conversion superhetrodyne and the oscillator is on a different range of frequencies. This is shown in the data tabulated below:

	Ordinary Old FM Receiver	JFM-90 FM Receiver
Tuning Range	42-50 mc.	42-50 mc.
IF Freq.	4.3 mc.	First: 23.15 to 27.15 mc. (tuned) Second: 4.3 mc. (fixed)
Osc. Range	37.7-45.7 mc.	18.85-22.85 mc.
Osc. Harmonic Used	2	3
New Tuning Range	79.7-95.7 mc.	79.7-115.7 mc.

If the ordinary old FM receiver is re-alligned so that it tunes up to [illegible] mc., it will cover a range of approximately [illegible] to [illegible] mc. on the new band.

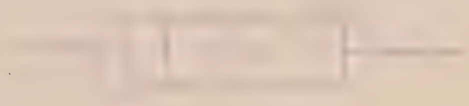
Two circuits for making this modification are shown in Fig. 2. They differ in that in one the input coil is tuned by a variable capacitor whereas in the other distributed capacity is relied upon for tuning. These parts should be mounted inside the receiver case where the coil can pick up energy from the local oscillator.

Figure 2 appears on page 4, TI-4558.

To get good reception on the new band a good antenna should be erected. Such an antenna is described on page TI-[illegible], and the proper way of erecting it is discussed. If a directional dipole is desired, there are several makes now available commercially.

C_1 10 mmf. capacitor
C_2 3-30 mmf. trimmer capacitor
L_1 10 Turns [illegible] double enamel covered wire on 1W Allen Bradley or Ohmite resistor whose value is 2.0 meg. or greater
L_2 12 Turns [illegible] double enamel covered wire on 1W Allen Bradley or Ohmite resistor whose value is 2.0 meg. or greater
L_3 [illegible] transformer primary of [illegible] receiver. The existing center tap [illegible] must be removed.
X_1 [illegible] crystal

Fig. 3



Xtal Dwg.

[illegible]
Technical Manager

References:
Converting FM Receivers for Use on the New 88-108 Mc. Band — IBS Bulletin Summer 1946 P. 21

TI-4452-5, IBS Technical Data Book (Engineering Note No. 10)
TI-8950 IBS Technical Data Book (Engineering Note No. 9)

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Technical Department Engineering File Number [illegible]

STUDIO AND CONTROL ROOM FACILITIES REQUIRED for a CAMPUS BROADCASTING STATION

Unique Requirements of College Broadcasting

The facilities required to enable a campus station to present a variety of well-produced programs are more extensive than the facilities needed by many full-time broadcasting stations. This is true for the following reasons:

1) Only a limited number of hours a day are available to students for work at the station.

2) The station must originate most of its programs because there are no good network facilities.

3) A campus station should be expected to broadcast a high percentage of "live" programs, because it is on the air only a few hours a day, during the peak listening period of its audience.

When the above facts are considered, it is obvious that a campus station should have at least two good-sized studios, with a control room for each studio. This arrangement permits one studio to be on the air, while the second is being used for a rehearsal. Standard broadcast stations having two studios, especially when one studio is large and the other is small, usually provide a single control room to serve both studios. This arrangement is not suitable when it is necessary to use both studios at once, as is the case in a campus radio station where students must rehearse and produce shows on the air at the same time.

Need for Master Control

Since two studios, each having a control room, offer two points for program origination, it is necessary to have some place in the station's facilities where either point may be selected to go on the air. It is possible to provide these switching facilities in either control room, but the circuits in one control room are thereby rendered more complex, and this leads to confusion. This is especially true when the control room used to route the program is not originating the program, but instead is also being used for a rehearsal in the adjoining studio.

[illegible]

Besides having switching circuits to select which studio is to be used at a given time, Master Control provides the best place to locate record and transcription play-back equipment. From Master Control it is then possible to handle recorded programs without tying up a large studio. If a small speech or announce studio is provided for Master Control it will permit better monitoring of announcements from Master Control, as well as more favorable acoustical conditions for the announcer.

Master Control should also have all facilities for handling remote programs, and for feeding the station's signal to its [illegible]. Thus, circuits may be needed to feed the program to other stations, as well as to the campus r.f. transmission system. It often is feasible to locate the transmitter in Master Control, but often it is better to locate it at a point more advantageous from the standpoint of the transmission system, and connect Master Control with the transmitter by means of an audio line.

Planning Station Growth

In the above paragraphs the needs for a campus station have been discussed, and it is apparent that a well-equipped station should have:

1) At least two studios, each with separate control room.
2) A Master Control with announce studio.

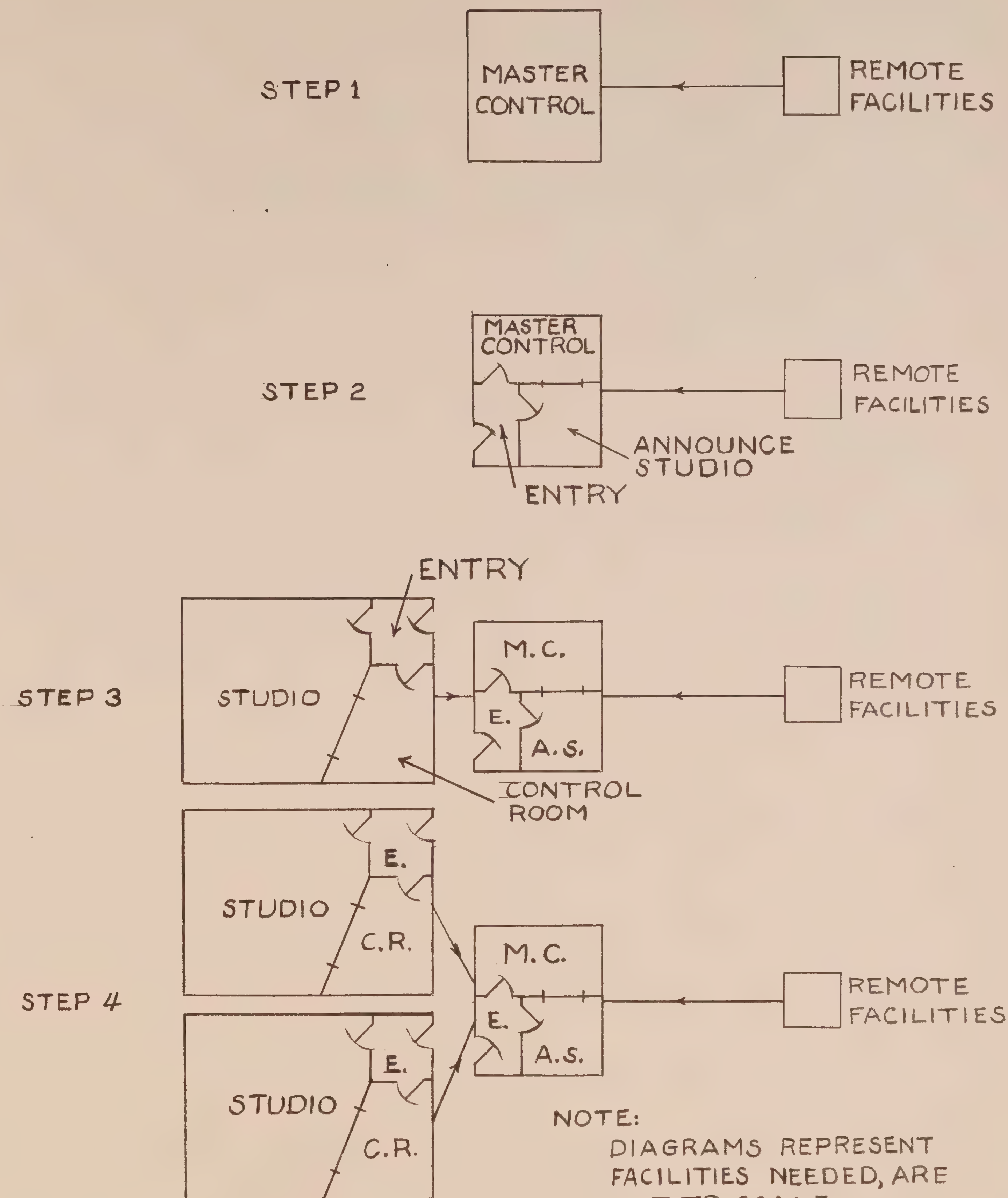
Obviously, it is seldom possible to start a campus station with these facilities. However, if it is realized that they will some day be needed, it is possible to plan a logical path for station growth which will lead to this arrangement with the least difficulty.

When initial operations are to be limited to one or two rooms, these should be located with the thought of future expansion in mind. It is important not to have to move the station in order to obtain additional space.

Drawing R1005 shows several logical steps in station growth. When initial operations are restricted to one room, install the equipment in this room as if it were Master Control for the station. Programs needing a larger room can be handled as remotes from a room borrowed for the occasion. Admittedly, these temporary facilities are far inferior than would be provided by a good, large studio.

Operations from the single room can be improved by installing a small announce studio. If initially the room is large enough, it can be partitioned off. The announce studio floor area should be at least 6 ft. by 8 ft., preferably considerably more. Master Control should be at

H1096



NOTE:
DIAGRAMS REPRESENT FACILITIES NEEDED, ARE NOT TO SCALE.

TITLE SKETCH SHOWING STEPS IN GROWTH CAMPUS STATION

BEGUN BY D.W. Borst April 4, 1946 FINISHED BY D.W. Borst April 14, 1946	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1096	GH PY DL R
REVISED:			PRINTS TO

T152 7-7-45

least 10 ft. by 10 ft., or equivalent.

When the announce studio is installed programs originating in Master Control can be monitored over a loud speaker. This permits much more precise and expert performance by the control man, who is enabled to hear the program under more normal conditions than over a head set. If the announce studio is more than a booth, and can accomodate two or three people, it can be used for interview programs.

An important step is taken in station growth when a studio and control room are installed. These facilities need not be on the same floor as master control, provided they are convient to reach by the station staff. The master control operator does not have to observe the action in the studio. This is up to the studio control man. When this studio and control room are built program production on the station can be greatly expanded because it is possible then to conduct rehearsals while the station is on the air.

If interest in the station grows, it will probably be found desirable to have a second studio and control room. Preferably, the control room facilities should be duplicates of the first, so as to avoid additional circuit and operating complexity; but the studio may be a different size, depending on the space available.

Master Control Equipment and Interconnections

Below is a list of the equipment needed in Master Control. Drawing W1007 indicates how this equipment is interconnected.

1) Record turntables and pickups: at least two, one with provisions for 33 1/3 r.p.m. transcriptions.

2) Microphones: At least one for control man, one for announcer.

3) Mixer for pickups and microphones: At least four channels.

4) Lines terminating facilities: Patch panel, switches, line booster amplifier(s) to overcome line losses, a means to feed "cue" over the lines to remote points.

5) Booster amplifiers [illegible] as "line booster amplifiers" [illegible]

6) Channel amplifiers to feed program signals out: One or more of the following channels will be needed:

a) Transmitter channel.
b) Outgoing audio lines channel.
c) Recording equipment channel.
d) Cue channel, to feed cue to studios and remote points.

Channel amplifiers are provided with input selector switches which make it possible to do several programs at once, such as broadcast from one studio and make a recording from another. The exception is the cue channel amplifier, which is always connected to relay the program going over the air.

7) Program monitor with speaker interlocked with control man's microphone: This monitor is connected to monitor the program at all times, preferably by using a detector built into the transmitter.

8) Roving monitor with speaker interlocked with control man's microphone: This monitor is connected to a multi-contact switch, so that the control man may monitor any booster or channel amplifier he desires, or other signals of interest.

9) Program volume indicator: This is a VU meter connected to the output of the channel amplifier feeding the transmitter.

10) Roving volume indicator: This is a VU meter connected to the input of the roving monitor, so that the level of the signal being monitored may be measured.

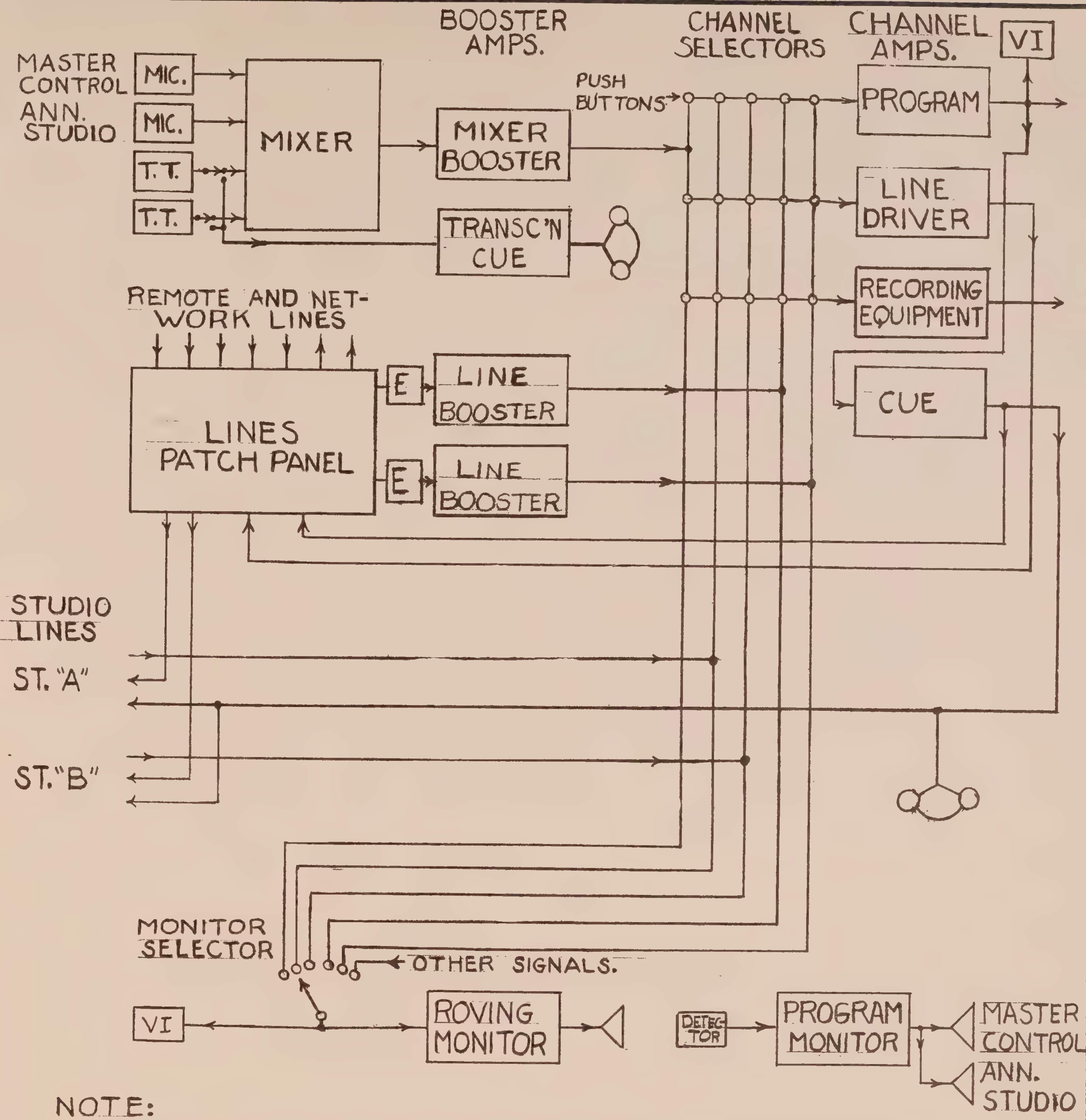
Relatively few of the station staff will be expected to be able to operate all of the above equipment with facility. However, the steps which must be followed in order to originate a program from master control and the associated speech studio should be well known to all the control men. It can be done, if necessary, a record show may be produced by one man handling the controls and announcing at the same time.

Only programs originating from master control pass through the master control mixer; all other signals are amplified by booster amplifiers, and then they are routed to the proper channel amplifiers by switching, rather than by mixing.

Studio Control Equipment and [illegible]

The control [illegible]

H1097



NOTE:
INTERLOCK MICROPHONES AND MONITOR SPEAKERS.

TITLE LINE DIAGRAM OF BASIC MASTER CONTROL FACILITIES

BEGUN BY D.W.Bost april 4, 1946 / FINISHED BY D.W.Bost april 14, 1946	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1097
REVISED: II Apr. 20, 1946		

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PRINTS TO

T152 7-7-45

flexibility in microphone placement. One or two lines input channels are also required. These are needed for special effects, such as a filter microphone, and also to permit building into a program material from an outside source.

Two monitor amplifier and speaker systems are needed, one system for the control room, and one for the studio. Both should be able to monitor the studio mixer output, and "cue", which is the signal going over the air. The studio monitor also should permit switching of a microphone in the control room, so the control man may talk back to the studio. The studio can talk to the control room over the studio microphones.

The studio controls consist of gain controls, and associated selector switches, and so they are far less difficult to master than the controls in master control. Special circuits can be set up in advance by the master control operator, the studio control operator need know only how to operate a relatively few simple dials and switches. This control simplification permits the control man more easily to follow the production, and do a better job. It also means that more students can qualify as studio control men, which increases the ability of the station to originate a full schedule of "live" programs.

Circuit and Construction Details

Subsequent pages in this section of the Technical Data Book will deal in greater detail with the equipment arrangements required in master control and studio control rooms. Also, construction methods for studios and control rooms will be discussed. For circuit diagrams of suitable amplifiers and mixers, refer to section TI2000.

Engineering Note
Number 12

March 30, 1947

A CLOCK SYNCHRONIZATION SYSTEM

By ingenious use of a photocell and thyratron relay circuit the engineering staff of station WKCR, Columbia University, is able to synchronize any number of clocks at the station with a clock in their control room at the same instant that this clock is synchronized by Western Union Time Service. In addition to accurately setting the station's clocks every hour, on the hour, the photoelectric device also energizes an audio oscillator which feeds a 440 cycle tone to the transmitter for 1.5 seconds exactly on the hour, thus giving a very accurate audible time check.

The station staff has found this installation to be of great value in their production work, since the staff has the incentive of an audible timing signal to keep their programs running on schedule, and also because the control room and studio clocks are in synchronism at all times.

The operating cost of the installation is not excessive since any number of clocks may be operated from the one clock which is leased from Western Union Time Service. In addition to costing less to operate than several rented clocks, the photoelectric system may be used to operate a time signal as well.

WKCR's Engineering Director, Alan Sobel, has given the following detailed explanation of how this installation was made. With this information, it should be possible for any IBS station in a city having Western Union Time Service to make a similar installation. Mr. Sobel's explanation follows:

"A time signal is a decided asset to any college station. The necessity of 'meeting the beep' improves the timing on most shows, and the signal adds a professional air to the station's operations. In addition, the signal can be used to synchronize other clocks, thus making sure that all studios and control rooms are operating on the same time.

"The system used at WKCR utilizes the Western Union Time Service obtainable in many large cities. This service operates with clocks manufactured by the Self Winding Clock Company of Brooklyn, New York.

These clocks are pendulum movement, spring-wound clocks of excellent accuracy, which wind themselves automatically on power furnished by two self-contained dry cells. They are reset every hour by an impulse (3 volts DC--duration 1.5 seconds) from Western Union over leased wires. The clock we obtained has a red light which goes on when the clock synchronizes. It is this light which we use for our time signal. A photocell in front of it operates a thyratron, which in turn furnishes operating current for a relay.

"The circuit diagram (91107) tells the whole story. The thyratron circuit is the standard light-operated relay circuit as described in the RCA phototube manual 'RCA Phototubes.' A 919 tube was used as fulfilling the requirements of being

[illegible] mounted [illegible] the high-speed [illegible] ... [illegible] with the advantage of being [illegible]. The [illegible] (of adequate voltage rating) are mounted [illegible] next to the clock. The photocell is shielded [illegible] a small hole [illegible], while the leads are [illegible]. [illegible] fastened to the clock [illegible], and a bracket under the clock keeps [illegible].

"The relay, oscillator, and isolation amplifiers are mounted on a three inch relay rack panel in the main relay rack. The relay is a [illegible] 110 volt [illegible] unit which fills the requirements quite adequately. Its two contacts key the clock circuit and the plate voltage for the 'beep' respectively. (One additional clock, obtained outright from the Self Winding Clock Company, cost $85, is mounted in the studio. Others will be purchased as needed. All will be synchronized from the one Western Union clock, and all for the rental ([illegible] per year in New York City) of the clock. Since this rental applies to each clock rented from W.U., the additional clock, neglecting the cost of the time signal unit, will have paid for itself in two years.)

"The design of the "beep" part of the circuit was dictated by the operational design of the station. The transmitters can be switched to any one of three channels, and one isolation amplifier was therefore built for each channel, feeding the time signal to the transmitters regardless of what program material they are transmitting. The channel busses are 500 ohm unbalanced circuits. (The unbalance makes it possible to connect the input grid of any amplifier across the channel without designing transformers or other special arrangements.) Since the amplifiers are connected across the bus at all times, their plate resistors must be fairly high so as not to load each channel excessively. 50,000 ohms has proved a quite satisfactory value for this resistor, while the resistance bus makes coupling a simple matter. However, since the load circuit is only 500 ohms, a low reactance capacitor must be used for reasonable energy transfer. In a previous edition of this circuit the signal from the oscillator was quite weak, so 2 mfd was considered necessary. The later model does not need such large capacitors, but they were left in to save labor. (Note: Only one of the three 6J5 isolation amplifiers are shown on ED[illegible]. The other two are identical.)

"In the first edition of this unit a neon bulb was used as a relaxation oscillator. This [illegible] very balky and proved quite unstable, so a cathode [illegible] oscillator was substituted. A filter choke was used as the tuned circuit inductance [illegible] capacitor [illegible] resonates it at 440 cycles. This oscillator [illegible] and produces an excellent note. Experiments carried out by friends of the writer [illegible] that it is extremely stable with respect to plate voltage and will oscillate over a very wide frequency range. A fuller description will be found in [illegible] (Frank C. Alexander, "A [illegible] Oscillator." QST, [illegible] "Hints and Kinks").

"Plate voltage is supplied from the main power supply of the station. The additional drain of a few milliamperes for [illegible] every hour [illegible] for the [illegible] circuit and heater voltage, from a [illegible] transformer [illegible] directly from the line. All power circuits are fused.

"One addition is to be made to the unit. A one revolution-per-hour motor [illegible] will be used to [illegible] AC to the heater [illegible] primary for only [illegible] minutes every hour. This [illegible] tube life [illegible] [illegible]."

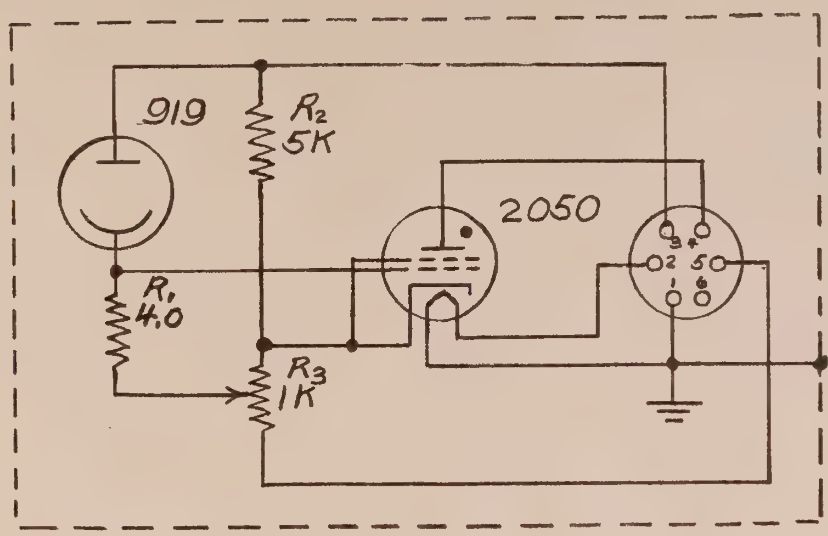
Note: Further details concerning the facilities of WHCR are given in IBS printed form T145 which is a reprint of "Studio and Control Room Design" by W. R. Hutchins which appeared in Electronics magazine, August 1945 issue.

David W. Borst
Technical Manager

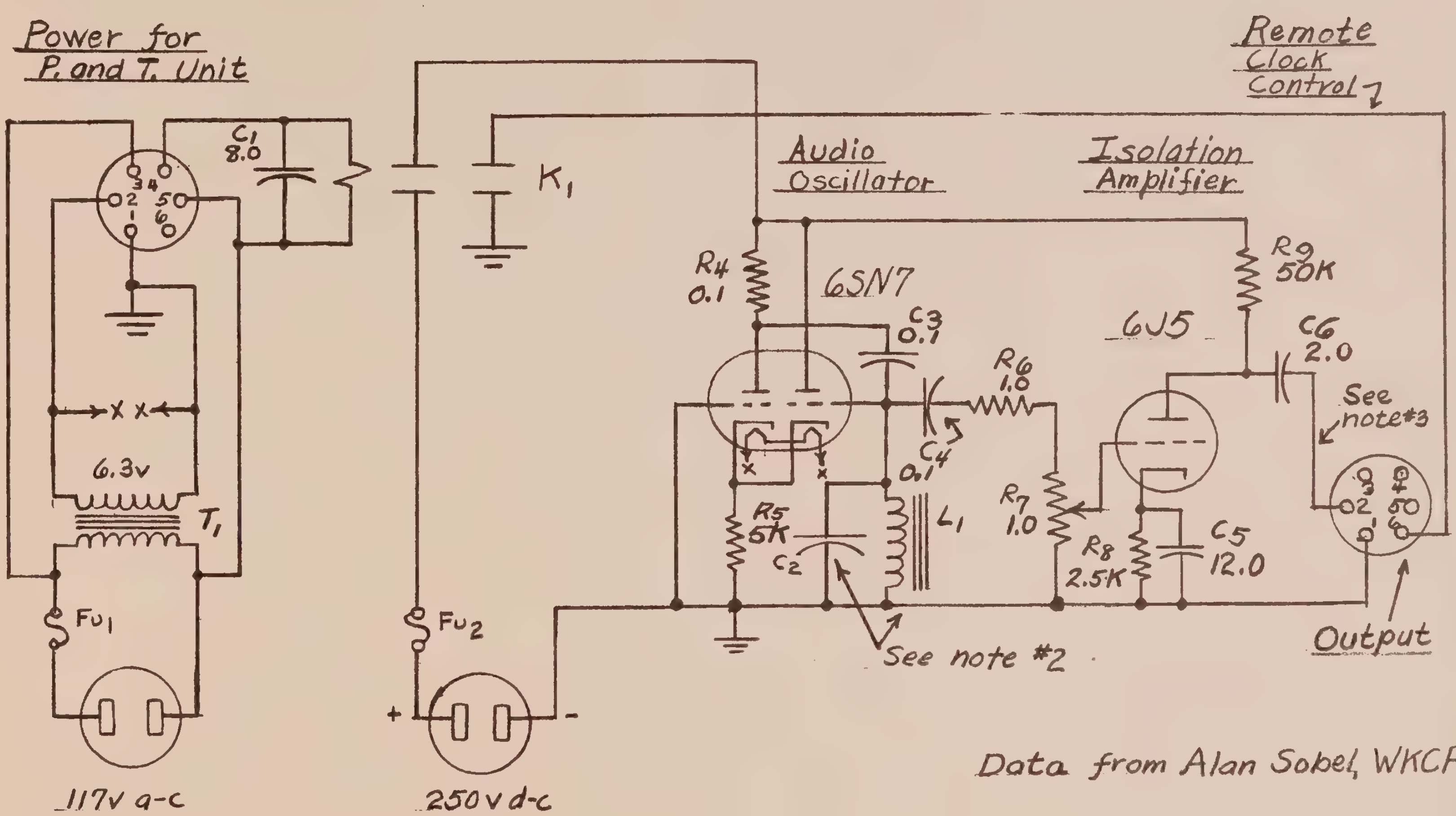
Engineering Files are issued from time to time by the Technical Department, Intercollegiate Broadcasting System, [illegible]

It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for handy future reference.

Technical Department Engineering File Number T15.96.



Photocell and Thyratron Unit



Data from Alan Sobel, WKCR

NOTES:

1) Values in megohms or microfarads unless shown otherwise.
2) L_1 and C_2 selected for 440 cycles. Try 10H and 250μμf.
3) Isolation amplifier shown is suitable for feeding unbalanced 500 or 600 ohm circuit. This stage will require modification to feed other types of transmitter input circuits.

TITLE CLOCK CONTROL AND TIME SIGNAL UNIT

FILE REF.: T15.96

BEGUN BY DuBost Nov 5, 1946	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1107	GH PY DL R PRINTS TO
FINISHED BY DuBost Nov 26, 1946			
REVISED:			

Engineering Note
Number 17

April 11, 1948

Sound Isolation and Sound Treatment of Studios

Immediately following drawing H1107 in the Third Edition of the DC Technical Data Book you will find five drawings pertaining to studio construction. This engineering note is intended to explain the use of these drawings.

H1125 Sound Insulated Wall Construction
H1126 Sound Insulated Ceiling Construction
H1127 Sound Insulated Floor Construction
H1128 Sound Insulated Window Construction

These four drawings summarize recommendations concerning construction of studios so that outside noises will not penetrate into the studio, and so that the control room and studio will be similarly isolated. These drawings cover most of the aspects of the problem except sound insulated door construction. A good sound insulated door is not easy to build; many stations prefer to purchase doors guaranteed to give a specified degree of isolation. These are usually of heavy construction--two or three inches thick-- with one or more rubber steps which seal the edges of the door tightly when the door is closed, thus preventing the sound outside the door from leaking into the studio.

These drawings do not discuss the treatment of the interior walls of the studio to give correct reverberation time, "liveness", etc. Refer to the discussion under H1098 for pointers on this.

None of these drawings discusses the related problems of optimum studio dimensions, which help in the control of reverberation within the studio; and station layout, which is important if the station's facilities are to be used effectively.

If you are working on plans for new studios it is suggested you write for more detailed information on these subjects. We have it, but not yet worked up into shape for general distribution.

H1098 Design Data for Polycylindrical Diffusers

Polycylindrical diffusers are coming into very prominent use in radio and motion picture studios. They are better than splays, and it is not usually necessary to cover more than two thirds of the studio walls with them; other surfaces may be doors, windows and sound absorbent acoustical tile. They are easy to make --the assembly method shown on H1098 is more of a guide; the plywood may be nailed to the 2xx (or 2x4) studs on the top of the studs

instead of being forced into the slots shown. Diffusers must be made of plywood and should be of various sizes as indicated on E1098.

David W. Borst

Engineering Notes are issued from time to time by the Engineering Department, Intercollegiate Broadcasting System, [illegible] Hamilton Annex, Columbia, U., New York 27, N.Y.

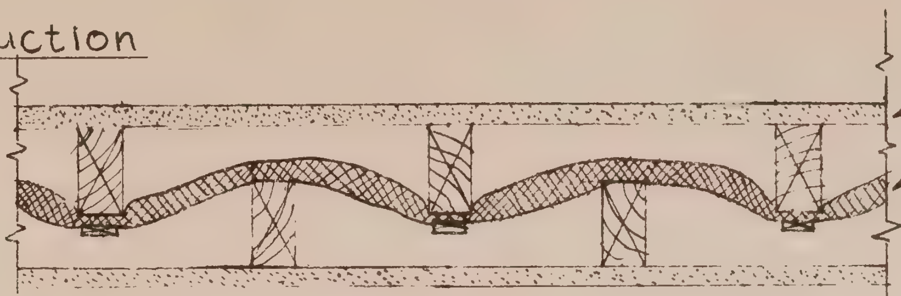
It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for handy future reference.

Engineering Department File Number T15.51

If your station does not have the Third Edition of the Technical Data Book write us about it.

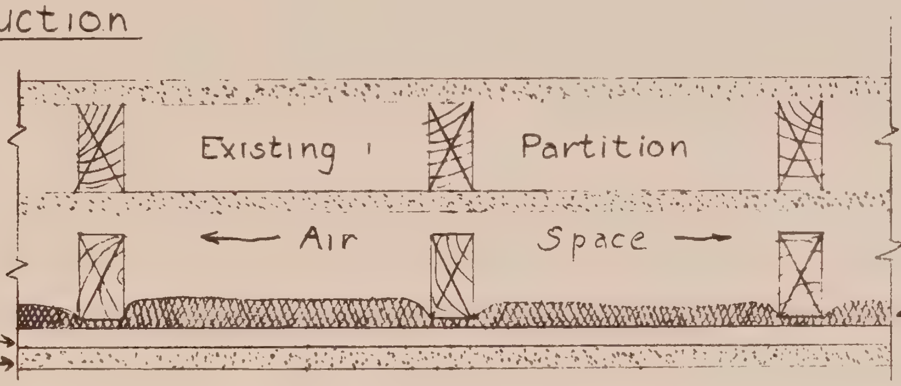
H1125

New Construction



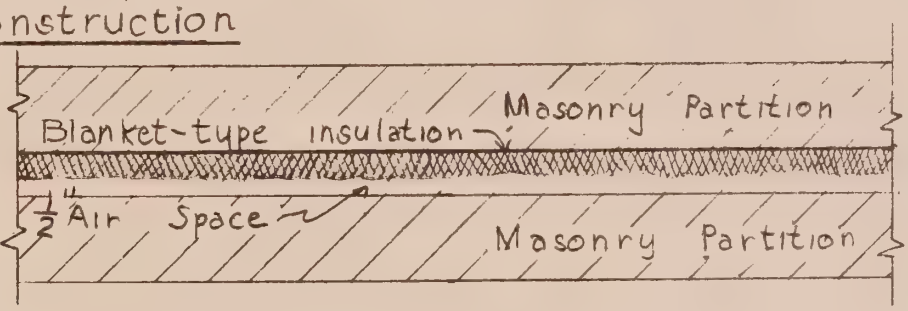
Note: construct partition wall of staggered 2"x 4" studs, on 2"x6" plate – each set 16" o.c. Pad plates with insulation. Weave blanket-type insulation between studs, securing to one set. Avoid open joints between strips of insulation. Apply interior finish to partition as desired.

Old Construction



Note: erect partition of 2"x4" studs on 2"x4" plate, at least 1" from existing wall. Pad plates with insulation. Apply blanket-type insulation over surface. Overlap insulation strips. Apply 1"x2" or 2"x2" furring at right angles to studs as base for interior finish.

Masonry Construction



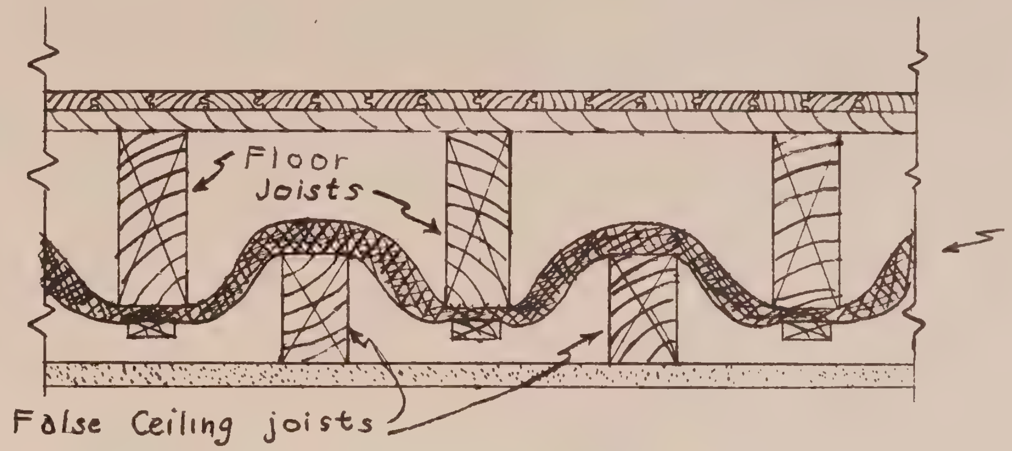
Note: construct partition in two separated sections. The blanket-type insulation is applied to inner surface during construction. Secure insulation with galvanized roofing nails into mortar joints. Lap all joints at least 3", with uniform tension on all strips.

TITLE **Sound Insulated Wall Construction**

BEGUN BY E.R. Schiffmacher 6/18/'47	INTERCOLLEGIATE BROADCASTING	H1125	PY
FINISHED BY E.R. Schiffmacher 7/1/'47	SYSTEM TECHNICAL DEPT.		DL
REVISED:			R
			PRINTS TO

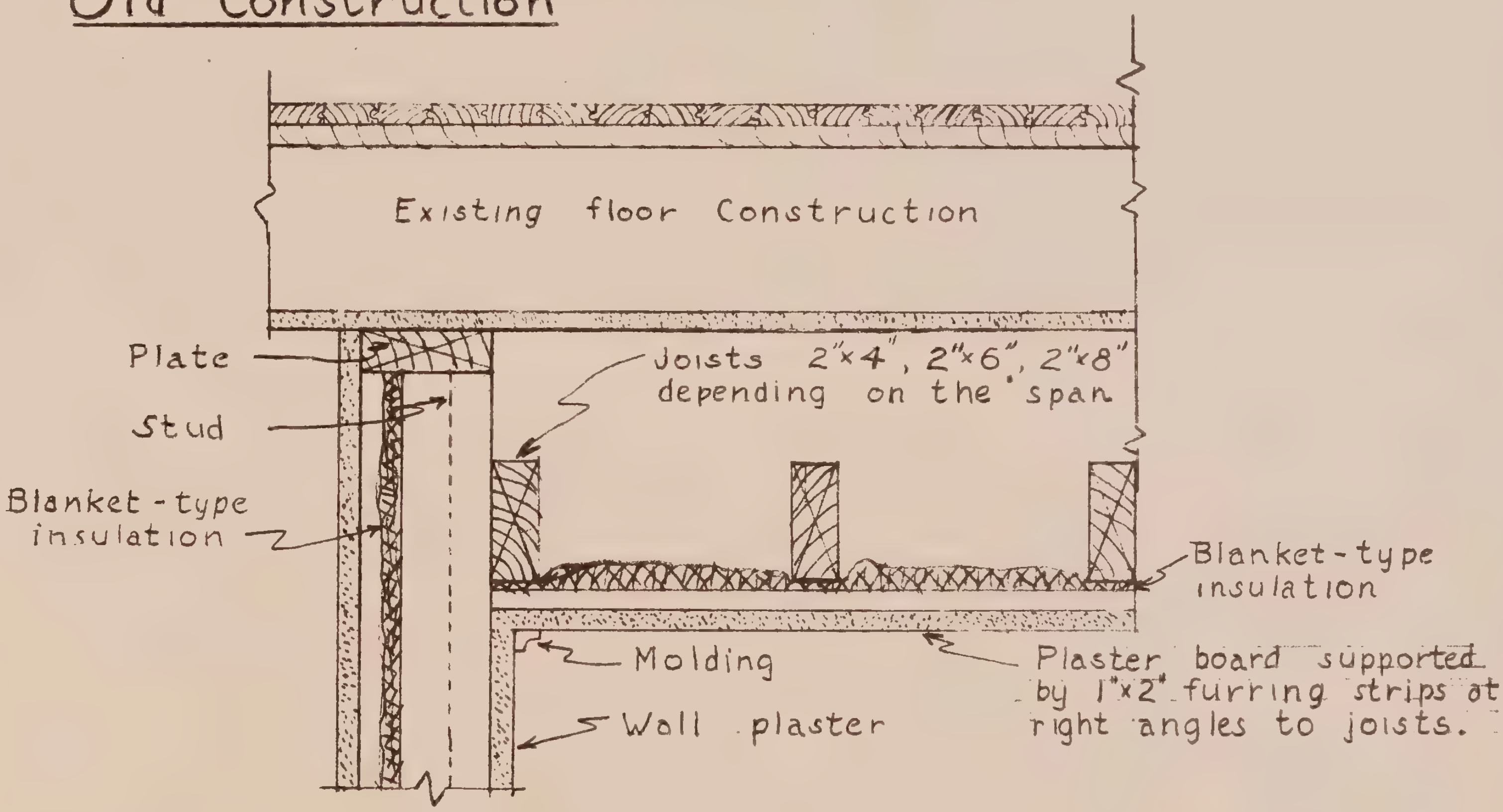
T162 7-7-45

New Construction



Note: stuff blanket-type insulation into the break over plate at top of wall partitions.

Old Construction

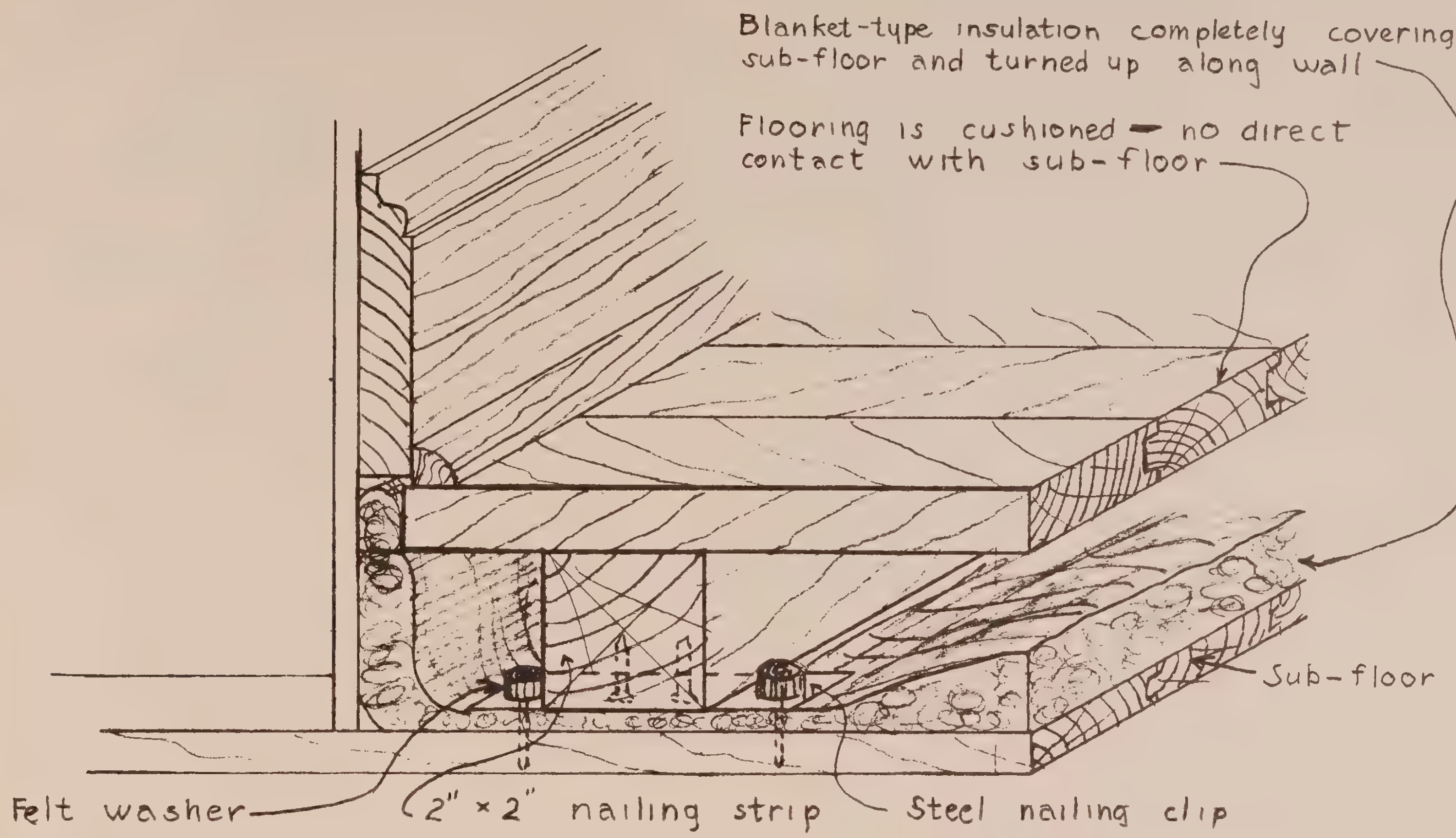


Note: wall may be either new construction or old construction. This sketch shows new construction double wall.

TITLE **Sound Insulated Ceiling Construction**

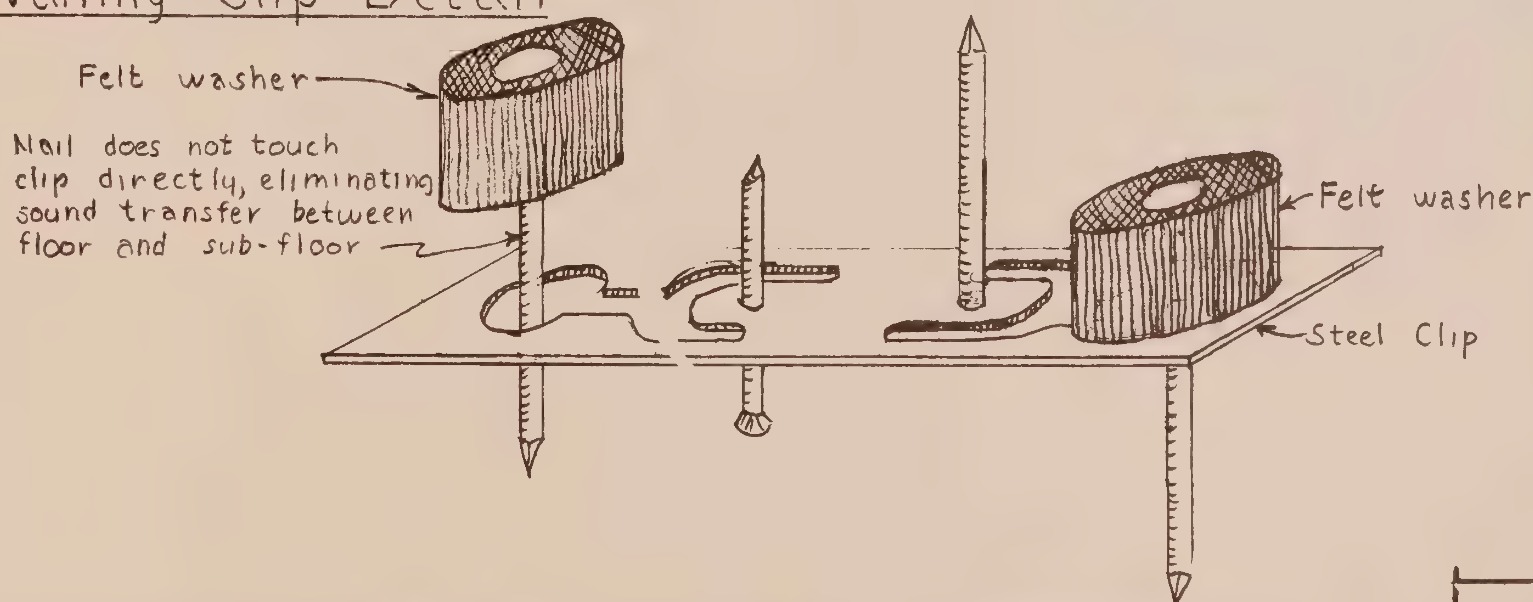
BEGUN BY E.K. Schiffmacher 7/18/1947 FINISHED BY E.K. Schiffmacher 7/19/1947		INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.				H1126		PY DL R PRINTS TO
REVISED:								

New or Old Construction



Note This method of sound insulation may be applied to an existing wall or ceiling as an alternate to methods shown on H1125 and H1126. Plaster is substituted on walls and ceiling for flooring shown above. Do NOT use this method for walls with observation windows or door.

Nailing Clip Detail

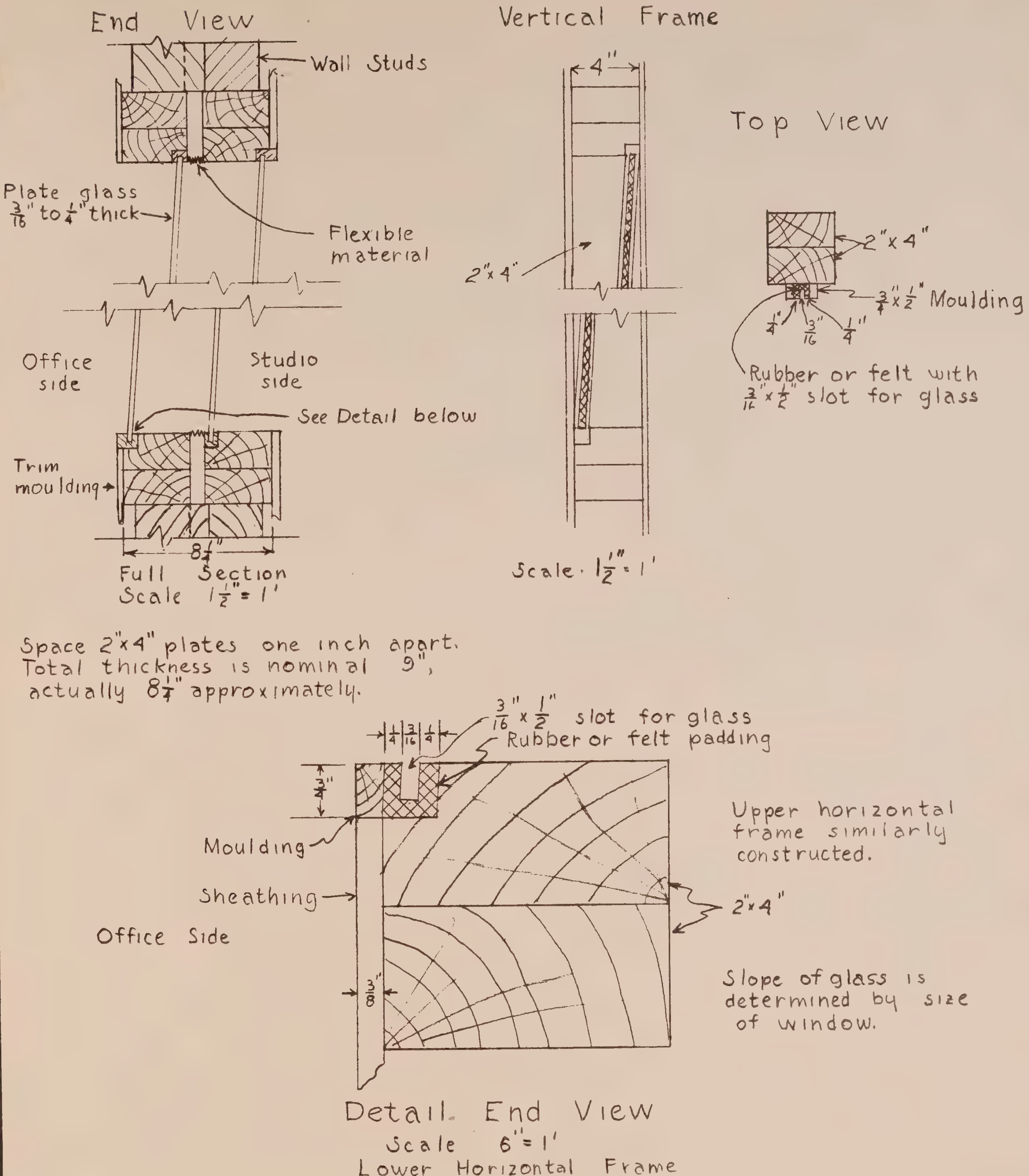


TITLE **Sound Insulated Floor Construction**

BEGUN BY E R Schiffmacher - June 18 '47	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1127	PY DL R PRINTS TO
FINISHED BY E R Schiffmacher - Aug 12 '47			
REVISED:			

T152 7-7-45

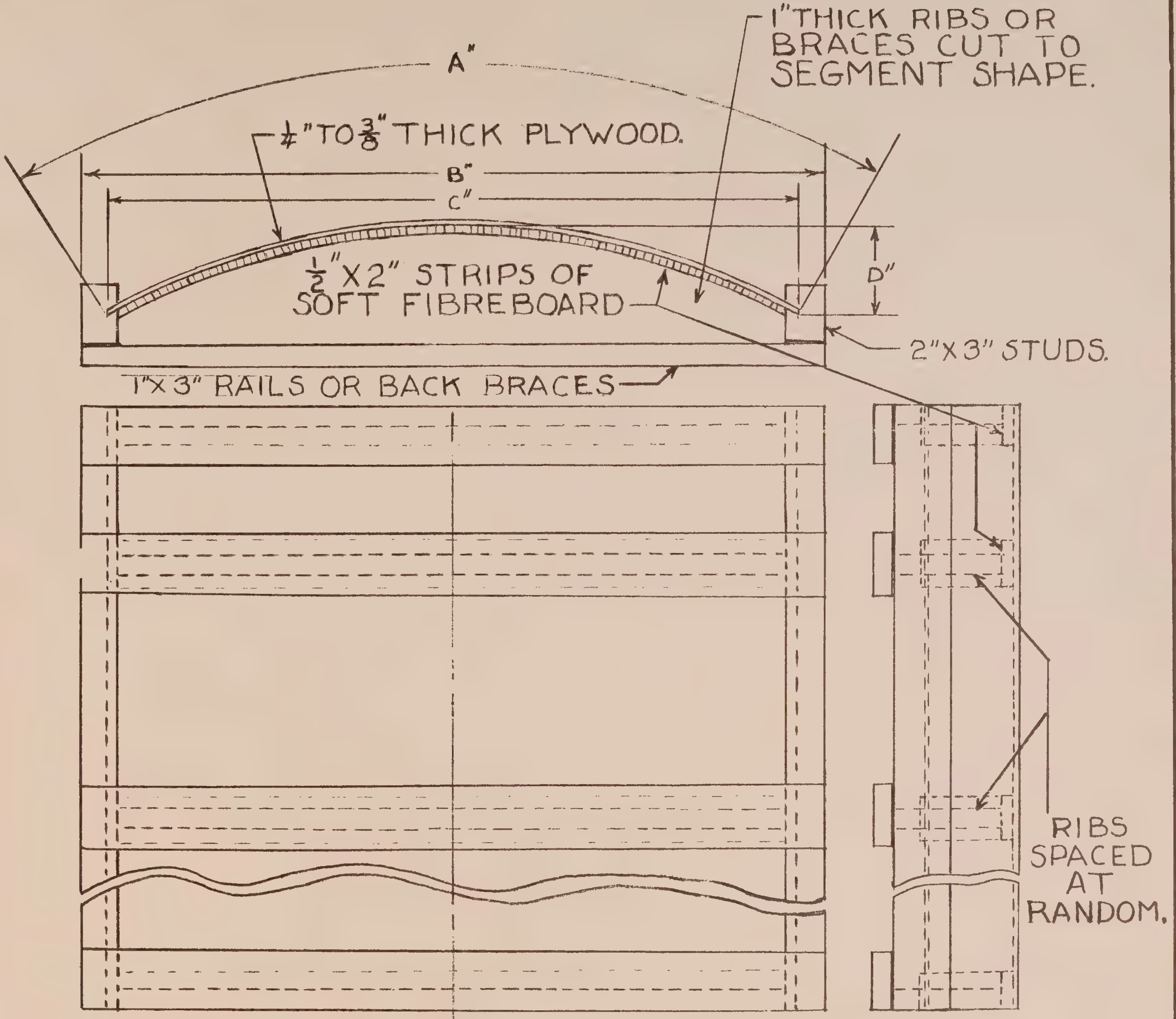
H1128



TITLE **Sound-Insulated Window Construction**

BEGUN BY E.R. Schiffmacher 6/18/47	INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.	H1128	PY
FINISHED BY E.R. Schiffmacher 8/10/47			DL
REVISED:			R
			PRINTS TO

T152 7-7-45



NOTE:
LENGTH TO SUIT ℄
REQUIREMENTS.
USE ALL THREE
SIZES, AT RANDOM.

A	B	C	D
36	$37\frac{1}{2}$	$34\frac{1}{2}$	$4\frac{1}{2}$
42	$42\frac{1}{2}$	$39\frac{3}{4}$	6
48	$47\frac{1}{2}$	$44\frac{1}{2}$	$7\frac{3}{4}$

TITLE DESIGN DATA FOR POLYCYLINDRICAL DIFFUSERS

GH
PY
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PRINTS TO

BEGUN BY D.W. Borst April 9, 1946
FINISHED BY D.W. Borst April 14, 1946
REVISED.

INTERCOLLEGIATE BROADCASTING SYSTEM TECHNICAL DEPT.

H1098

[illegible]

[illegible] of an almost [illegible] [illegible] [illegible] is more apt to be replaced [illegible] for a [illegible] [illegible] [illegible] the [illegible] work of [illegible] [illegible] of a [illegible] [illegible] The [illegible] is a cultural [illegible] for [illegible], [illegible] rituals, or [illegible] pair of [illegible] [illegible] can be substituted [illegible] [illegible] In [illegible] [illegible] [illegible] [illegible] and [illegible] [illegible].

Today, I believe these [illegible] [illegible] of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

[illegible]

Let us look more closely at the miniature tubes mentioned above. The 9002 is a triode with indirectly heated cathode, a 6.3 volt heater, and capable of operating at plate voltages up to a value of 250 volts. Its amplification factor is twenty-five, transconductance 2200 micromhos, and plate resistance 11,400 ohms, rated plate dissipation 1.0 watts. It is of the midget type - the short, stubby, size of miniature. I have found the 9002 of particular use in applications where low grid current is essential. At a plate current of 0.5 milliamperes, I have used the tube in a circuit maintaining an impedance of [illegible] megohms between the grid and cathode, and I am sure we could go higher if necessary. The 6AT6 is a hi-mu duplex-diode triode; mu=70, g_m=1200, r_p=58,000. The 6AU6 and 6BA6 are pentodes, the former being a sharp cut-off type with g_m=5200 micromhos, and the latter is a remote cut-off type with g_m=4400 micromhos. The 6AK5 and 6AK6 are pentodes which have been useful to me in amplifier and current stabilizer circuits. The 6AH6 is a high-gain video pentode that Raytheon has recently put into production. A transconductance of 9000 micromhos is claimed and as such, this tube should get plenty of use in compact wide-band amplifiers. The 12AU7 is a brand-new tube by RCA containing two separate triodes. It isn't a pure miniature since it is a little bit bigger in diameter than the normal miniature and has a nine pin base rather than the usual seven.

The 2E30 seems to have good possibilities in a variety of applications. I have a pair of them on hand and plan to test them next spring in a 10 watt hi-fi audio circuit and a twenty watt transmitter. It seems to me that this would form a good, compact, high performance plate-modulated output combination for a college carrier-current system. Twenty watts is quite adequate for most installations and ten watts of audio is just the right amount for plate modulation. The 2E30 is manufactured by Hytron. It is a filament type tube (6.0 volts [illegible]) which requires a two-second warm-up period before application of high voltages. This means that apparatus supplied by the usual [illegible] power supply can be turned on safely with one switch, since at least two seconds will elapse before the rectifier filaments heat and plate voltage is developed.

A compilation of data on presently available miniatures follows. It is not necessarily complete since every month sees the introduction of a new type. [illegible]

[illegible]

[illegible]

Note:
Translation follows on pages TI-8054 and [illegible].

Engineering Notes are issued from time to time by the Technical [illegible] Columbia Broadcasting System, [illegible]

It is suggested that a copy be bound in [illegible] for ready, future reference.

Technical Department Engineering File Number: [illegible]

[illegible]	[illegible]		[illegible]				
[illegible]	Trigger Tube	–	1000	–	–		[illegible]
[illegible]	H-F Diode	1.4 h	[illegible] peak inverse	–	–		[illegible]
[illegible]	R-F Pentode	1.4 f	[illegible]	–			
[illegible]	Pentagrid Converter	1.4 f	90		[illegible]	[illegible]	
[illegible]	P.A. Pentode	1.4 f	90		[illegible]	[illegible] meg	[illegible]
[illegible]	Diode-Pentode	1.4 f	[illegible]		[illegible]	[illegible]	
[illegible]	Remote Cut-off Pentode	1.4 f	90		[illegible]	[illegible] meg	[illegible]
[illegible]	Sharp Cut-off Pentode	1.4 f	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	Thyratron	6.3 h	[illegible]				[illegible]
[illegible]	Beam Pentode	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	P.A. Pentode	1.4-2.8 f	150		[illegible]	[illegible] meg	[illegible]
[illegible]	R-F Twin Triode	1.4-2.8 f	135	35	[illegible]	[illegible]	[illegible]
[illegible]	P.A. Pentode	1.4-2.8 f	[illegible]		[illegible]	[illegible] meg	[illegible]
[illegible]	P.A. Pentode	1.4-2.8 f	90		[illegible]	[illegible] meg	[illegible]
[illegible]	P.A. Pentode	1.4-2.8 f	90		[illegible]	0.1 meg	[illegible]
[illegible]	R-F Pentode	6.3 h	300		[illegible]	[illegible] meg	[illegible]
[illegible]	[illegible] Pentode	6.3 h	300		[illegible]	[illegible]	
[illegible]	R-F Pentode	6.3 h	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	P.A. Pentode	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	Twin Triode	[illegible]	[illegible]				[illegible]
[illegible]	[illegible] P.A.	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
[illegible]	[illegible]-Triode	[illegible]	[illegible]		[illegible]	[illegible]	

[illegible]	[illegible]					[illegible]
6L4	Gas Triode					[illegible]
6J4	UHF Triode					[illegible]
[illegible]	Twin Triode					[illegible]
6X4	Full Wave Rectifier	6.3	peak [illegible]			[illegible]
[illegible]	Twin Triode	6.3	100			[illegible]

216

[illegible]

[illegible]	Remote Cut-off [illegible] Pentode	26.5	[illegible]	[illegible]	[illegible]
[illegible]	[illegible] Triode	26.5	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	26.5	[illegible]	[illegible]	[illegible]

Engineering Note
Number 14

April 2, 1948

Preferred Electron Tubes

The equipment designs based on the use of a selected list of electron tubes offer the obvious advantages of fewer different types of tubes to procure when the equipment is placed in service and fewer different types to maintain as spares. Certain electron tubes have been selected as preferred by the Armed Forces and by the larger radio equipment manufacturers and these types are readily available, both through regular distributors and on the Government surplus equipment market. Similarly, as time goes on, these preferred types are less likely to become difficult to procure.

The following tabulation has been prepared to list tubes in this preferred category which are of greatest interest to designers of broadcast equipment. It is a wise policy to use only these tubes when designing new equipment, and even to consider changing older equipment over to the use of these preferred types.

Function	Heater Voltage and Socket Type				
	1.4 V miniature	6.3 V miniature	6.3 V octal	6.3 V loctal	misc.
Diodes	1A3	6AL5	6H6		
Diode-Triodes	1S4* (pentode)		6SQ7 6SR7		
Triodes		9002	6J5		
Twin Triodes	3A4	6J6	6SL7 6SN7	7F7* 7F8	
Pentodes-remote	1T4	9003	6SG7 6SK7		
Pentodes-sharp	1L4	9001 6AK5	6J7* 6SJ7		
Converter	1R5		6SA7 6L7(mixer)*		

Function	Heater Voltage and Socket Type				
	1.4 v. mineature	6.3 v miniature	6.3 v octal	6.3 v [illegible]	[illegible]
Power Output	3A4	6AK6**	6A5**		117N7*
			6L6		
			6F6		
			6Y6*		
			6V6		
			6W6		
			1613*		
Indicators			6AF6		
			6E5		
Rectifiers		5R4	6X5		2576*
		5U4			117Z6*
		5Y3			
		83			
		80*			
Cathode Ray			2AP1		
			3BP1		
			3GP1**		
			5CP1		
Voltage Regulators				OA3/VR75	
				OC3/VR105	
				OD3/VR150	

*Useful types not included in latest listing of Army-Navy preferred types.

** Promising new types not yet on Army-Navy preferred list.

Note: G, GT or GT/G designations have been omitted to save space.

DAVID W. BORST

Engineering Notes are issued from time to time by the Engineering Department, Intercollegiate Broadcasting System, WKCR Hamilton Annex, New York 27, N. Y.

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Engineering Department File Number T15.80.

If your station does not have the Third Edition of the Technical Data Book write us about it.

Preferred Resistor Values

Preferred Number Chart

These preferred values are based on a series of preferred numbers, being multiples of ten of these numbers. The chart on the next page lists the preferred numbers used for 20 percent, 10 percent, and 5 percent tolerance resistors. One manufacturer has stated that he will offer resistors in the values derived from the 5 percent tolerance series of numbers in 10 percent and 20 percent tolerance resistors, as well.

Plus or minus 10 percent tolerance resistors are accurate enough for most audio and radio frequency equipment, and the sizes given in the 10 percent column are more than adequate for those purposes. These values will be available from all popular resistor vendors. Values not listed can be made up from resistors in series or in parallel, or chosen from the five percent tolerance series.

Substitute Values

Two values very often used before the adoption of the RMA preferred values, and not found among these values, are 2.5 and multiples of ten, and 5.0 and multiples of ten. In place of these values 2.2 and multiples of ten and 4.7 and multiples of ten, respectively, should be used.

All diagrams published by NBS will call for preferred values in fixed resistors rated two watts and below. If dealers do not as yet have these ratings, the nearest value may be substituted in most cases. If the size specified is critical, a five percent tolerance resistor will be specified. Greater care should be taken when choosing a substitute part if this closer tolerance is specified.

RMA PREFERRED NUMBER CHART

For Fixed Composition Resistors

Tolerance ±20%	Tolerance ±10%	Tolerance ±5%
1.0	1.0	1.0
		1.1
	1.2	1.2
		1.3
1.5	1.5	1.5
		1.6
	1.8	1.8
		2.0
2.2	2.2	2.2
		2.4
	2.7	2.7
		3.0
3.3	3.3	3.3
		3.6
	3.9	3.9
		4.3
4.7	4.7	4.7
		5.1
	5.6	5.6
		6.2
6.8	6.8	6.8
		7.5
	8.2	8.2
		9.1

Engineering Note
Number 9

March 30, 1947

Fixed Crystal Rectifiers

The 1N34 and similar fixed crystal rectifiers provide performance equal to or superior to that of a 6H6 diode, and because they have almost unlimited life and require no heater power they are very attractive to the campus station designer for:

Detector-in off - the-air monitor.
Rectifier-in db. meter (ok for steady state readings; do not use
 this type of instrument for a volume indicator).
Rectifier-in standing wave and r.f. power measuring devices.
Rectifier-in test instruments.
Converter-FM receiver adapter unit to permit tuning new band.

For further details refer to the Sylvania Electric advertisements which have appeared in recent issues of [illegible], and the articles in the Sept. 1946, and April 1947 issues of [illegible].

David W. Borst
Technical Manager

Engineering Notes are issued from time to time by the Technical Department, Intercollegiate Broadcasting System, 705 Sanders Ave., Schenectady [illegible]

It is suggested that a copy be bound in the IBS Technical Data Book at the page indicated for handy future reference.

Technical Department Engineering File Number [illegible].

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10:15 - 10:45 - Korfer
10:45 - 11:30 - Bolgeano
11:30 - 2:00 - Morrison

M.H./26